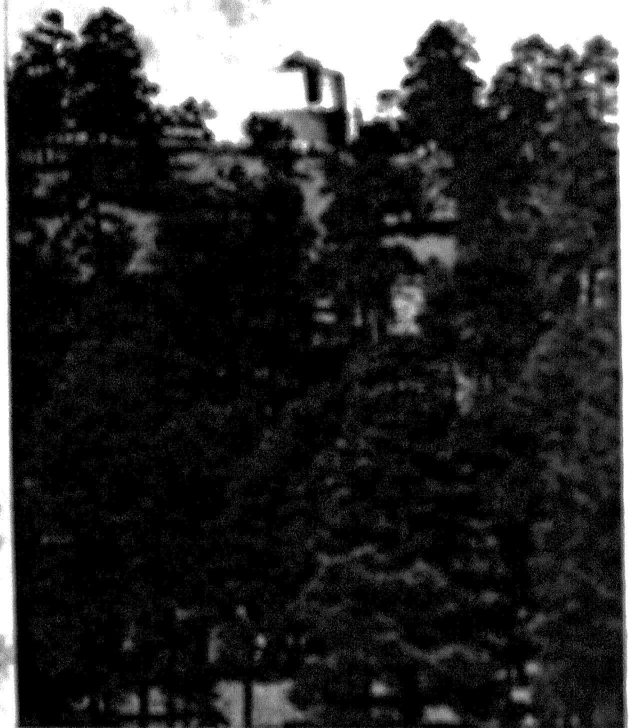
MARS AND ITS CANALS



MARS

AND ITS CANALS

BY

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To

G. V. SCHIAPARELLI

THE COLUMBUS OF A NEW PLANETARY WORLD

THIS INVESTIGATION UPON IT

IS APPRECIATIVELY

INSCRIBED

PREFACE

Eleven years have elapsed since the writer's first work on Mars was published in which were recorded the facts gleaned in his research up to that time and in which was set forth his theory of their explanation. Continued work in the interval has confirmed the conclusions there stated; sometimes in quite unexpected ways. Five times during that period Mars has approached the earth within suitable scanning distance and been subjected to careful and prolonged scrutiny. Familiarity with the subject, improved telescopic means, and long-continued training have all combined to increased efficiency in the procuring of data and to results which have been proportionate. A mass of new material has thus been collected, — some of it along old lines, some of it in lines that are themselves new, — and both have led to the same outcome. In addition to thus pushing inquiry into advanced portions of the subject, study has been spent in investigation of the reality of the phenomena upon which so much is based, and in testing every theory which has been suggested to

account for them. From diplopia to optical interference, each of these has been examined and found incompatible with the observations. The phenomena are all they have been stated to be, and more. Each step forward in observation has confirmed the genuineness of those that went before.

To set forth science in a popular, that is, in a generally understandable, form is as obligatory as to present it in a more technical manner. If men are to benefit by it, it must be expressed to their comprehension. To do this should be feasible for him who is master of his subject and is both the best test of, and the best training to, that post. Especially vital is it that the exposition should be done at first hand; for to describe what a man has himself discovered comes as near as possible to making a reader the co-discoverer of it. Not only are thus escaped the mistaken glosses of second-hand knowledge, but an aroma of actuality, which cannot be filtered through another mind without sensible evaporation, clings to the account of the pioneer. Nor is it so hard to make any well-grasped matter comprehensible to a man of good general intelligence as is commonly supposed. The whole object of science is to synthesize, and so simplify; and did we but know the uttermost of a subject we could make it singularly clear. Meanwhile technical phraseology,

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ON EXPLORATION

FROM time immemorial travel and discovery have called with strange insistence to him who, wondering on the world, felt adventure in his veins. The leaving familiar sights and faces to push forth into the unknown has with magnetic force drawn the bold to great endeavor and fired the thought of those who stayed at home. Spur to enterprise since man first was, this spirit has urged him over the habitable globe. Linked in part to mere matter of support it led the more daring of the Aryans to quit the shade of their beech trees, reposeful as that umbrage may have been, and wander into Central Asia, so to perplex philologists into believing them to have originated there; it lured Columbus across the waste of waters and caused his son to have carved upon his tomb that ringing couplet of which the simple grandeur still stirs the blood: —

Á Castilla y á Leon
Nuevo mondo dió Colon;
(To Castile and Leon beyond the wave
Another world Columbus gave;)

it drove the early voyagers into the heart of the vast wilderness, there to endure all hardship so that they might come where their kind had never stood before; and now it points man to the pole.

Something of the selfsame spirit finds a farther field today outside the confines of our traversable earth. Science which has caused the world to shrink and dwindle has been no less busy bringing near what in the past seemed inaccessibly remote. Beyond our earth man's penetration has found it possible to pierce, and in its widening circle of research has latterly been made aware of another world of strange enticement across the depths of space. Planetary distances, not mundane ones, are here concerned, and the globe to be explored, though akin to, is yet very different from, our own. This other world is the planet Mars. Sundered from us by the ocean of ether, a fellow-member of our own community of matter there makes its circuit of the sun upon whose face features show which stamp it as cognate to that on which we live. In spite of the millions of miles of intervening matterless void, upon it markings can be made out that distantly resemble our earth's topography and grow increasingly suggestive as vision shapes them better; and yet among the seemingly familiar reveal aspects which are completely strange. But more than this: over the face of it sweep changes that show it to be

not a dead but a living world, like ours in this, and luring curiosity by details unknown here to further exploration of its unfamiliar ground.

To observe Mars is to embark upon this enterprise; not in body but in mind. Though parted by a gulf more impassable than any sea, the telescope lets us traverse what otherwise had been barred and lands us at last above the shores we went forth to seek. Real the journey is, though incorporeal in kind. Since the seeing strange sights is the essence of all far wanderings, it is as truly travel so the eye arrive as if the body kept it company. Indeed, sight is our only far viatic sense. Touch and taste both hang on contact, smell stands indebted to the near and even hearing waits on ponderable matter where sound soon dissipates away; only sight soars untrammeled of the grosser adjunct of the flesh to penetrate what were otherwise unfathomable space.

What the voyager thus finds himself envisaging shares by that very fact in the expansion of the sense that brought him there. No longer tied by means of transport to seas his sails may compass or lands his feet may tread, the traveler reaches a goal removed in kind from his own habitat. He proves to have adventured, not into unknown parts of a known world, but into one new to him in its entirety. In extent alone he surveys what dwarfs the explorer's conquests

on Earth. But size is the least of the surprises there in store for him. What confronts his gaze finds commonly no counterpart on Earth. His previous knowledge stands him in scant stead. For he faces what is so removed from every day experience that analogy no longer offers itself with safety as a guide. He must build up new conceptions from fresh data and slowly proceed to deduce the meaning they may contain. Science alone can help him to interpretation of what he finds, and above all must he wean himself from human prejudice and earthbound limitation. For he deals here with ultramundane things. With just enough of cosmogony in common to make decipherment not despairable this world is yet so different from the one he personally knows as to whet curiosity at every turn. He is permitted to perceive what piques inquiry and by patient adding of point to point promises at last a rational result.

Like mundane exploration, it is arduous too; *ad astra per aspera* is here literally true. For it is a journey not devoid of hardship and discomfort by the way. Its starting-point preludes as much. To get conditions proper for his work the explorer must forego the haunts of men and even those terrestrial spots found by them most habitable. Astronomy now demands bodily abstraction of its devotee. Its deities are gods that veil themselves amid man-crowded marts and

impose withdrawal and seclusion for the prosecution of their cult as much as any worshiped for other reason in more primeval times. To see into the beyond requires purity; in the medium now as formerly in the man. As little air as may be and that only of the best is obligatory to his enterprise, and the securing it makes him perforce a hermit from his kind. He must abandon cities and forego plains. Only in places raised above and aloof from men can he profitably pursue his search, places where nature never meant him to dwell and admonishes him of the fact by sundry hints of a more or less distressing character. To stand a mile and a half nearer the stars is not to stand immune.

Thus it comes about that today besides its temples erected in cities, monasteries in the wilds are being dedicated to astronomy as in the past to faith; monasteries made to commune with its spirit, as temples are to communicate the letter of its law. Pioneers in such profession, those already in existence are but the precursors of many yet to come as science shall more and more recognize their need. Advance in knowledge demands what they alone can give. Primitive, too, they must be as befits the still austere sincerity of a cult, in which the simplest structures are found to be the best.

Still the very wildness of the life their devotee is

forced to lead has in it a certain fittingness for his post in its primeval detachment from the too earthbound, in concept as in circumstance. Withdrawn from contact with his kind, he is by that much raised above human prejudice and limitation. To sally forth into the untrod wilderness in the cold and dark of a winter's small hours of the morning, with the snow feet deep upon the ground and the frosty stars for mute companionship, is almost to forget one's self a man for the solemn awe of one's surroundings. Fitting portal to communion with another world, it is through such avenue one enters on his quest where the common and familiar no longer jostle the unknown and the strange. Nor is the stillness of the stars invaded when some long unearthly howl, like the wail of a lost soul, breaks the slumber of the mesa forest, marking the prowling presence of a stray coyote. Gone as it came, it dies in the distance on the air that gave it birth; and the gloom of the pines swallows up one's vain peering after something palpable, their tops alone decipherable in dark silhouette against the sky. From amid surroundings that for their height and their intenancy fringe the absolute silence of space the observer must set forth who purposes to cross it to another planetary world.

But the isolation of his journey is not always so forbidding. His coming back is no less girt with grandeur

The Hermitage

of a different though equally detached a kind. Even before the stars begin to dim in warning to him to return, a faint suffusion as of half-suspected light creeps into the border of the eastern sky. Against it, along the far pine-clad horizon, mesa after mesa in shaggy lines of sentineling earth, stands forth dark marshaled in the gloom, informed with prescience of what is soon to come. Imperceptibly the pallor grows, blanching the face of night and one by one extinguishing the stars. Slowly then it takes on color, tingeing ever so faintly to a flush that swells and deepens as the minutes pass. One had said the sky lay dreaming of the sun in pale imagery at first that gathers force and feeling till the dreamer turns thus rosy red in slumbering supposition of reality. Then the blush dies out. The crimson fades to pink, the pink to ashes. The stars have disappeared and yet it is not day. It is the supreme moment of the dawn, the hush with which the Earth awaits its full awakening. For now again the color gathers in the east, not with the impalpable suffusion it had before but nearer and more vivid. No longer reflectively remote, rays imminent of the sun strike the upper air, the most adventurously refrangible turning the underside of a few stray clouds into flame-hued bars of glowing metal. They burn thus in the silent east first red, then orange, and then gold, each spectral tint in prismatic revelation coming to join the next till in a sudden

blinding burst of splendor the solar disk tops the horizon's rim.

Not less impressive is the journey when the afternoon watch has replaced the morning vigil by the drawing of the planet nearer to the sun. Lost in the brilliance of the dazzling sky, the planet lies hid from the senses' search. The quest were hopeless did not the mind guide the telescope to its goal. To theory alone is it visible still, and so to its predicted place the observer sets his circles, and punctual to the prophecy the planet swings into the field of view. One must be dulled by long routine to such mastery of mind not to have the act itself clothe with a sense of charmed withdrawal the object of his quest.

So much and more there are of traveler's glimpses by the way, compensation that offsets the frequent discomfort, and even balking of his purpose by inopportune cloud. For the best of places is not perfect, and a storm will sometimes rob him of a region he wished to see. He must learn to wait upon his opportunities and then no less to wait for mankind's acceptance of his results; for in common with most explorers he will encounter on his return that final penalty of penetration, the certainty at first of being disbelieved.

In such respect he will be even worse off than were the other world discoverers of the fifteenth and sixteenth centuries. For they at least could offer material proof

of things that they had seen. Dumb Indians and gold spoke more convincingly than the lips of the great navigators. To astronomy, too, that other world was due. Without a knowledge of the earth's shape and size got from Francisco of Pisa, Columbus had never adventured himself upon the deep. But more than this, an astronomer it was, in the person of Americus Vespucius, who first discovered the new world, by recognizing it as such; Columbus never dreaming he had lighted upon a world that was new. Nor does it impair one jot or tittle of his glory that he knew it not. Nothing can deprive him of the imperishable fame of launching forth into the void in hope of a beyond, though he found not what he sought but something stranger still.

So, curiously, has it been with the trans-etherian. To Schiaparelli the republic of science owes a new and vast domain. His genius first detected those strange new markings on the Martian disk which have proved the portal to all that has since been seen, and his courage in the face of universal condemnation led to exploration of them. He made there voyage after voyage, much as Columbus did on Earth, with even less of recognition from home. As with Columbus, too, the full import of his great discovery lay hid even to him and only by discoveries since is gradually resulting in recognition of another sentient world.

CHAPTER II

A DEPARTURE-POINT

AS the character of the travel is distinctive, so the outcome of the voyage is unique. If he choose his departure-point aright, the observer will be vouchsafed an experience without parallel on Earth. To select this setting-out station is the first step in the journey upon which everything depends. For it is essential to visual arrival that a departure-point be taken where definition is at its best. Now, so far as our present knowledge goes, the conditions most conducive to good seeing turn out to lie in one or other of the two great desert belts that girdle the globe. Many of us are unaware of the existence of such belts and yet they are among the most striking features of physical geography. Could we get off our globe and view it from without we should mark two sash-like bands of country, to the poleward side of either tropic, where the surface itself lay patently exposed. Unclothed of verdure themselves they would stand forth doubly clear by contrast. For elsewhere cloud would hide to a greater or less extent the actual configuration of the Earth's topography to an observer scanning it from space.

One of these sash-like belts of desert runs through southern California, Arizona, New Mexico, the Sahara, Arabia Petræa and the Desert of Gobi; the other traverses Peru, the South African veldt, and Western Australia. They are desert because in them rain is rare; and even clouds seldom form. In a twofold way they conduce to astronomic ends. Absence of rain makes primarily for clear skies and secondarily for steady air; and the one of these conditions is no less vital to sight than the other. Water vapor is a great upsetter of atmospheric equilibrium and commotion in the air the spoiler of definition. Thus from the cloudlessness of their skies man finds in them most chance of uninterrupted communion with the stars, while by suitably choosing his spot he here obtains as well that prime desideratum for planetary work, as near a heavenly equanimity in the air currents over his head as is practically possible.

From the fact that these regions are desert they are less frequented of man, and the observer is thus perforce isolated by the nature of the case, the regions best adapted to mankind being the least suited to astronomic observations. In addition to what nature has thus done in the matter, humanity has further differentiated the two classes of sights by processes of its own contriving. Not only is civilized man actively engaged in defacing such part of the Earth's surface as he comes in

contact with, he is equally busy blotting out his sky. In the latter uncommendable pursuit he has in the last quarter of a century made surprising progress. With a success only too undesirable his habitat has gradually become canopied by a welkin of his own fashioning, which has rendered it largely unfit for the more delicate kinds of astronomic work. Smoke from multiplying factories by rising into the air and forming the nucleus about which cloud collects has joined with electric lighting to help put out the stars. These concomitants of advancing civilization have succeeded above the dreams of the most earth-centred in shutting off sight of the beyond so that today few city-bred children have any conception of the glories of the heavens which made of the Chaldean shepherds astronomers in spite of themselves.

The old world and the new are alike affected by such obliteration. Long ago London took the lead with fogs proverbial wholly due to smoke, fine particles of solid matter in suspension making these points of condensation about which water vapor gathers to form cloud. With the increase of smoke-emitting chimneys over the world other centres of population have followed suit till today Europe and eastern North America vie with each other as to which sky shall be the most obliterate. Even when the obscuration is not patent to the layman it is evident to the meteorologist

or astronomer. By a certain dimming of the blue, smoke or dust reveals its presence high up aloft as telltalely as if the thing itself were visible. Some time since the writer had occasion to traverse Germany in summer from Göttingen to Cologne and in so doing was impressed by a cloudiness of the sky he felt sure had not existed when he knew it as a boy. For the change was too startling and extensive to be wholly laid to the score of the brighter remembrances of youth. On reaching Cologne he mentioned his suspicion to Klein, only to find his own inference corroborated; observations made twenty years ago being impracticable today. Two years later in Milan Celoria told the same story, the study of Mars having ceased to be possible there for like cause. Factory smoke and electric lights had combined to veil the planet at about the time Schiaparelli gave up his observations because of failing sight. With a certain poetic fitness the sky had itself been blotted just at the time the master's eye had dimmed.

America is not behind in this race for sky extinction. In the neighborhood of its great cities and spreading into the country round about the heavens have ceased to be favorable to research. Not till we pass beyond the Missouri do the stars shine out as they shone before the white man came.

Few astronomers even fully appreciate how much this means, so used does man get to slowly changing condi-

tions. It amounts, indeed, between Washington and Arizona to a whole magnitude in the stars which may be seen. At the Naval Observatory of the former sixty-four stars were mapped in a region where with a slightly smaller glass one hundred and seventy-two were charted at Flagstaff.

Besides their immediate use as observing stations these desert belts possess mediate interest on their own account in a branch of the very study their cloudlessness helps to promote, the branch here considered, the study of the planet Mars. They help explain what they permit to be visible. For in the physical history of the Earth's development they are among the latest phenomena and mark the beginning of that stage of world evolution into which Mars is already well advanced. They are symptomatic of the passing of a terraqueous globe into a purely terrestrial one. Desertism, the state into which every planetary body must eventually come and for which, therefore, it becomes necessary to coin a word, has there made its first appearance upon the Earth. Standing as it does for the approach of age in planetary existence, it may be likened to the first gray hairs in man. Or better still it corresponds to early autumnal frost in the passage of the seasons. For the beginning to age in a planet means not decrepitude in its inhabitants but the very maturing of this its fruit. Evolution of mind in its denizens continues

long after desolation in their habitat has set in. Indeed, advance in brain-power seriously develops only when material conditions cease to be bodily propitious and the loss of corporeal facilities renders its acquisition necessary to life.

The resemblance, distant but distinctive, of the climatic conditions necessary on earth for the best scanning of Mars with those which prove to be actually existent on that other world has a bearing on the subject worth considerable attention. It helps directly to an understanding and interpretation of the Martian state of things. Though partial only, the features and traits of our arid zones are sufficiently like what prevails on Mars to make them in some sort exponent of physical conditions and action there. Much that is hard of appreciation in a low, humid land shows itself an everyday possibility in a high and dry one. The terrible necessity of water to all forms of life, animal or vegetal, so that in the simple thought of the aborigines rain is the only god worth great propitiation upon the due observance of which everything depends, brings to one a deeper realization of what is really vital and what but accessory at best. One begins to conceive what must be the controlling principle of a world where water is only with difficulty to be had, and rain unknown.

But in addition to the fundamental importance of water, the relative irrelevancy of some other conditions

usually deemed indispensable to organic existence there find illustration too. On the high plateau of northern Arizona and on the still higher volcanic cones that rise from them as a base into now disintegrating peaks, the thin cold air proves no bar to life. To the fauna there air is a very secondary consideration to water, and because the latter is scarce in the lowlands and more abundant higher up, animals ascend after it, making their home at unusual elevations with no discomfort to themselves. Deer range to heights where the barometric pressure is but three fifths that of their generic habitat. Bear do the like, the brown bear of northern American sea-level being here met with two miles above it. Nor is either animal a depauperate form. Man himself contrives to live in comfort and propagate his kind where at first he finds it hard to breathe. Nor are these valiant exceptions; as Merriam has ably shown in his account of the San Francisco peak region for the Smithsonian Institution—a most interesting report, by the way — the other animals are equally adaptive to the zones of more northern latitudes on the American continent, zones paralleled in their flora and fauna by the zones of altitude up this peak. All which shows that paucity of air is nothing like the barrier to life we ordinarily suppose and is not for an instant to be compared with dearth of water. If in a comparatively short time an animal or plant

The San Francisco Peaks

accustomed to thirty inches of barometric pressure can contrive to subsist sensibly unchanged at eighteen, it would be rash to set limits to what time may not do. And this the more for another instructive fact discovered in this region by Merriam: that the existence of a species was determined not by the mean temperature of its habitat but by the maximum temperature during the time of procreation. A short warm season in summer alone decides whether the species shall survive and flourish; that it has afterward to hibernate for six months at a time does not in the least negative the result.

That the point of departure should thus prove of twofold importance, speeding the observer on his journey and furnishing him with a *vade mecum* on arrival, is as curious as opportune. Without such furtherance, to the bodily eye on the one hand and the mind's eye on the other, the voyage were less conclusive in advent and less satisfactory in attent.

CHAPTER III

A BIRD'S-EYE VIEW OF PAST MARTIAN DISCOVERY

WITH Mars discovery has from the start waited on apparent disk. To this end every optical advance has contributed from the time of Galileo's opera-glass to the present day. For apparent distance stands determined by the size of the eye. But although it is the telescopic eye that has increased, not the distance that has diminished, the effect has been kin to being carried nearer the planet and so to a scanning of its disk with constantly increasing particularity. Mankind has to all intents and purposes been journeying Marsward through the years. Any historic account of the planet, therefore, becomes a chronicle of seeming bodily approach.

Perhaps no vivider way of making this evident and at the same time no better preface to the present work could be devised than by putting before the eye in orderly succession the maps made of Mars by the leading areographers of their day, since the planet first began to be charted sixty-five years ago. The procedure is as much as possible like standing at the telescope and seeing the phenomena steadily disclose.

Seen thus in order the facts speak for themselves. They show that from first to last no doubt concerning what was seen existed in the minds of those competent to judge by systematic study of the planet at first hand, and furthermore, from their mutual corroboration, that this confidence was well placed. For, far from there being any conflict of authorities in the case, those entitled to an opinion in the matter prove singularly at one.

Beginning with Maedler in 1840 the gallery of such portraitures of the planet comprises those by Kaiser, Green and Schiaparelli, continued since Schiaparelli's time by the earlier ones of the present writer. To this list has been added one by Flammarion, which though not solely from his own work gives so just a representation of what was known at the date, 1876, as to merit inclusion. The remarkable drawings of Dawes and the excellent ones of Lockyer in 1862–1864 were never combined into maps by the observers, and though the former's were so synthesized by Proctor in 1867, the result was conformed to what Proctor thought ought to be and so is not really a transcript of the drawings themselves.

Each of the maps presented marked in its day the point areography had reached; and each tells its own story better than any amount of text. They are all made upon Mercator's projection and omit in

consequence the circumpolar regions. The later ones give, too, only so much of the surface as was shown at the opposition they record, for Mars, being tipped now one way, now another, regards the earth differently according to its orbital position. In comparing them, therefore, the equator must be taken for medial line. Mercator's projection has been the customary one for portraying Mars except for such oppositions as chiefly disclose the arctic pole. And this, too, with a certain poetic fitness. For it comes by right of priority to delineation of a new world; seeing that Mercator was the first to represent in a map the mundane new world in its entirety, by the rather important addition of North America to the southern continent already known, and to give the whole the title America with 'Ame' at the top of the map and 'rica' at the bottom.

In looking at the maps it is to be remembered that they are what we should call upside down, south standing at the top and north at the bottom. Inverted they show because this is the way the telescopic observer always sees the planet. The disk would seem unnatural to astronomers were it duly righted. Just the same do men in the southern hemisphere look at our own Earth topsy-turvy according to our view, the Sun being to the north of them and the cold to the south. Certain landmarks distinguishable in all the maps may serve for specific introduction. The V-shaped marking on the

equator pointing to the north is the Syrtis Major, the first marking ever made out upon the planet and drawn by the great Huyghens in 1659. The isolated oval patch in latitude 26° south is the Solis Lacus, the pupil of the eye of Mars; while the forked bay on the equator, discovered by Dawes, is the Sabaeus Sinus, the dividing tongue of which, the Fastigium Aryn, has been taken for the origin of longitudes on Mars.

Twelve maps go to make the series. They are as follows:—

	MAKER	DATE
I.	Map of Beer and Maedler	1840
II.	" " Kaiser	1864
III.	" " Flammarion (Résumé) . .	1876
IV.	" " Green	1877
V.	" " Schiaparelli	1877
VI.	" " "	1879
VII.	" " "	1881
VIII.	" " "	1884
IX.	" " Lowell	1894
X.	" " "	1896
XI.	" " "	1901
XII.	" " "	1905

If these maps be carefully compared they will be found quite remarkably confirmatory each of its predecessor. To no one will their inter-resemblance seem more salient than to draughtsmen themselves. For none know better how surprisingly, even when two

men have the same thing under their very noses to copy, their two versions will differ. Judgment of position and of relative size is one cause of variation; focusing of the attention on different details another. What slight discrepancies affect the maps are traceable to these two human imperfections. Maps IV and V make a case in point: it was to his new-found canals that Schiaparelli gave heed to the neglect of a due toning of his map; while Green, less keen-eyed but more artistic, missed the delicate canaliform detail to make a speaking portraiture of the whole.

Amid the remarkable continuity of progression here shown, in which each map will be seen to be at once a review and an advance, we may, nevertheless, distinguish three stages in the perception of the phenomena. Thus we may mark:—

I. A period of recognition of larger markings only; 1840–1877
II. A period of detection of canals intersecting the bright regions or lands; 1877–1892
III. A period of detection of canals traversing the 'seas' and of oases scattered over the surface; 1892–1905

Each period is here represented by four charts; and each expresses the result of a more minute and intimate acquaintance with the disk than was possible to the one that went before. To realize, however, how accurate

each was according to his lights it is only necessary to have the seeing grow steadily better some evening as one observes. He will find himself recapitulating in his own person the course taken by discovery for all those who went before, and in the lapse of an hour live through the observational experience of sixty years; in much the same way that the embryological growth of an individual repeats the development historically of the race.

Two verses of Ovid, which the poet puts into the mouth of Pythagoras, outline with something like prophetic utterance the special discoveries which mark the three periods apart. Ovid makes Pythagoras say of the then world:—

> Vidi ego, quod fuerat quondam solidissima tellus
> Esse fretum; vidi factas ex aequore terras;
>
> — OVID, *Metamorphoses* XV, 262.
>
> (Where once was solid ground I've seen a strait;
> Lands I've seen made from out the sea.)

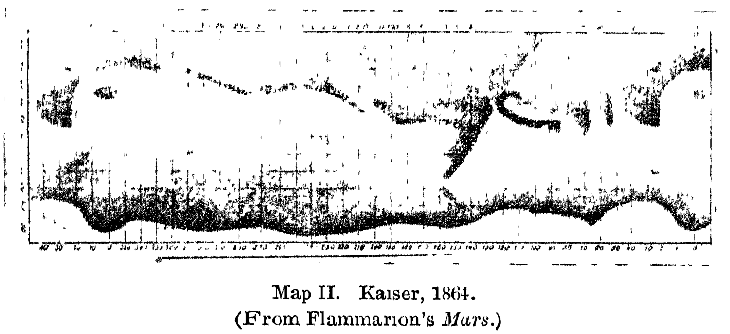
True as the verses are of Earth, the poet could not have penned them otherwise had he meant to record the course of astronomic detection on Mars. For they sound like a presentiment of the facts. A surface thought at first to be part land, part water; the land next seen to be seamed with straits; and lastly the sea made out to be land. Such is the history of the subject, and words could not have summed it more suc-

cinctly. "Vidi ego, quod fuerat quondam solidissima tellus esse fretum" rings like Schiaparelli's own announcement of the discovery of the 'canals.' Indeed, I venture to believe he would have made it had he chanced to recall the verse. So "vidi factas ex aequore terras" tells what has since been learned of the character of the seas.

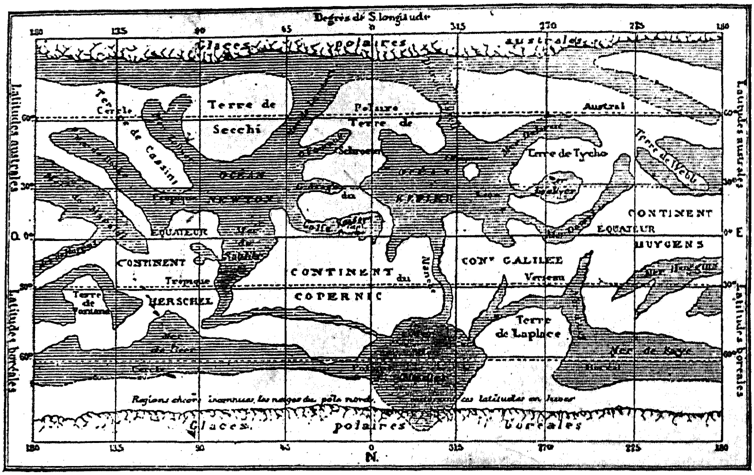
Of the three periods the first was that of the main or fundamental markings only. It came in with Beer and Maedler, the inaugurators of areography. That they planned and executed their survey with but a four-inch glass shows that there is always room for genius at the top of any profession and that instruments are not for everything in its instrumentality. Up to their day the reality of the planet's features had been questioned by some people in spite of having been certainly seen and drawn by Huyghens and others. Beer and Maedler's labors proved them permanent facts beyond the possibility of dispute.

The second period was the period of the discovery of the now famous canals, — a new era in the study of Mars opened by Schiaparelli in 1877 (Map V). Unsuspicious of what he was to stumble on, he seized the then favorable opposition to make, as he put it, a geodetic survey of the planet's surface. He hoped this undertaking feasible to the accuracy of micrometric measurement. His hopes did not belie him. He

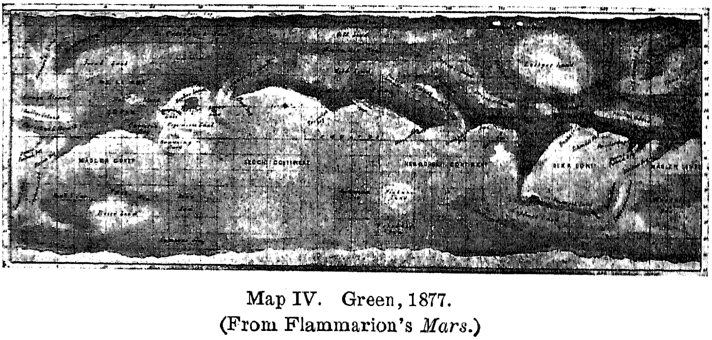
Map I. Beer and Maedler, 1840.



Map II. Kaiser, 1864.
(From Flammarion's *Mars*.)



Map III. Résumé by Flammarion, 1876.
(From Flammarion's *Mars*.)



Map IV. Green, 1877.
(From Flammarion's *Mars*.)

found that it was possible to measure his positions with sufficient exactness to make a skeleton map on which to embody the markings in detail — and thus to give his map vertebrate support. But in the course of his work he became aware of hitherto unrecognized ligaments connecting the seas with one another. Instead of displaying a broad unity of face the bright areas appeared to be but groundwork for streaks. The streaks traversed them in all directions, tesselating the continents into a tilework of islands. Such mosaic was not only new, but the fashion of the thing was of a new order or kind. Straits, however, Schiaparelli considered them and gave them the name *canali*, or channels. How unfamiliar and seemingly impossible the new detail was is best evidenced by the prompt and unanimous disbelief with which it was met.

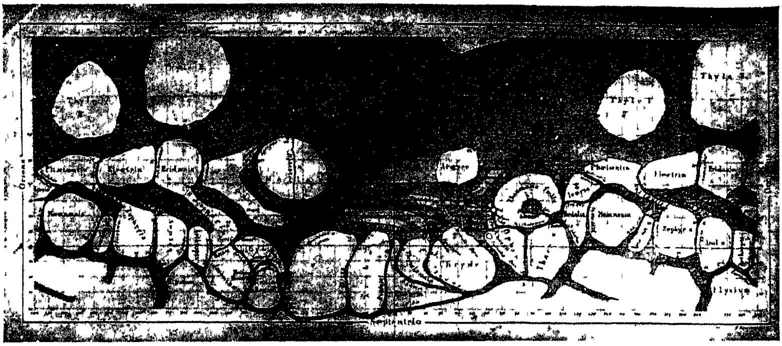
Unmoved by the universal scepticism which rewarded what was to prove an epoch-making discovery, Schiaparelli went on, in the judgment of his critics, from bad to worse — for in 1879 (Map VI) he took up again his scrutiny of the planet to the detecting of yet more particularity. He re-observed most of his old canals and discovered half as many more; and as his map shows he perceived an increased regularity in his lines.

In 1881–1882 (Map VII) he attacked the planet again and with results yet further out of the common. His lines were still there with more beside. If they had

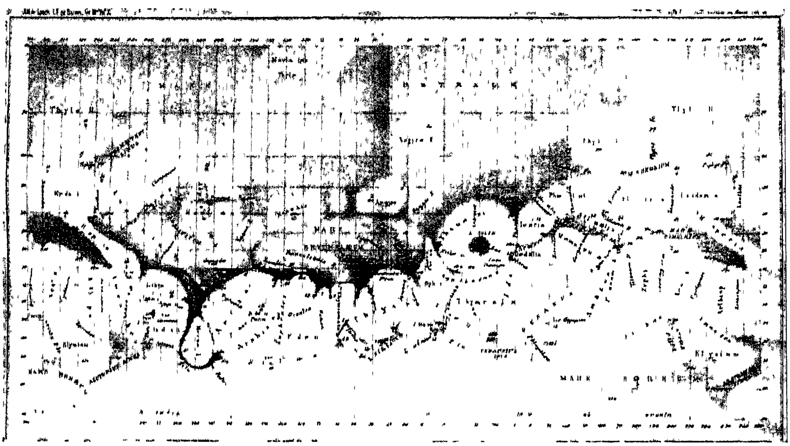
looked strange before, they now appeared positively unnatural. Not content with a regularity which seemed to the sceptics to preclude their being facts, he must needs see them now in duplicate. To the eyes of disbelief this was the crowning stroke of factitiousness.

In consequence no end of adverse criticism was heaped upon his observations by those who could not see. But curiously enough, — what did not attract attention, — the blindness of the critics was as much mental as bodily. For they failed to perceive that the very unnaturalness which seemed to them to discredit his observations really proved their genuineness. His discoveries were so amazing that any change in strangeness simply went to confirm the universal scepticism and clouded logic. Yet properly viewed, a pregnant deduction stands forth quite clearly on a study of the maps.

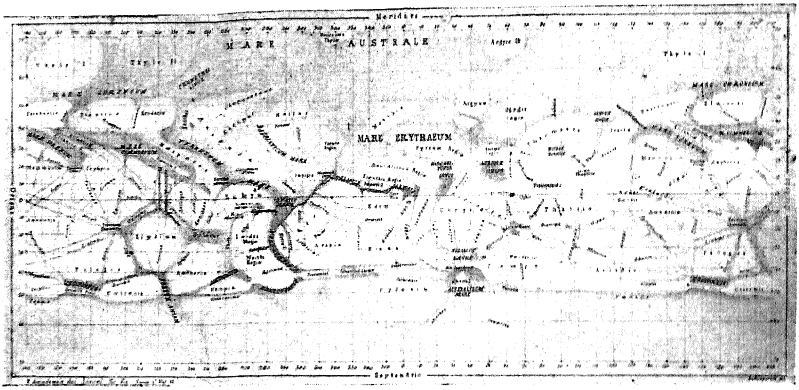
On comparing maps V, VI and VII an eye duly directed is struck by a difference in the aspect of the lines. In his first map the 'canals' are depicted simply as narrow winding streaks, hardly even roughly regular and by no means such departures from the plausible as to lie without the communicatory pale. Indeed, to a modern reader prepared beforehand for geometric construction they will probably appear no 'canals' at all. Certainly the price of acceptance was not a large one to pay. But like that of the Sibylline



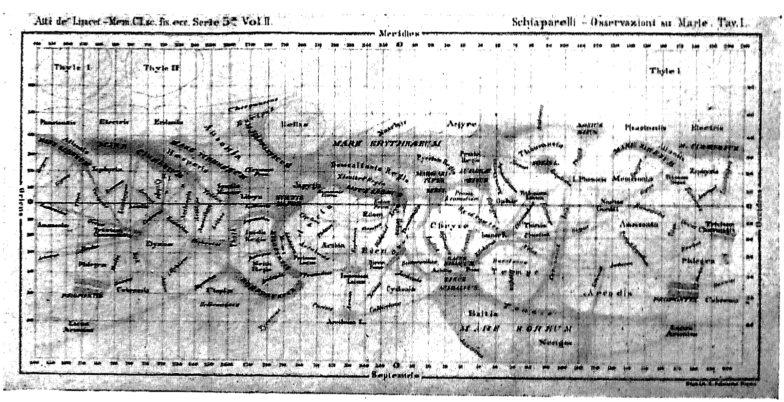
Map V. Schiaparelli, 1877.
(From Schiaparelli's *Memoria.*)



Map VI. Schiaparelli, 1879.
(From Schiaparelli's *Memoria.*)



Map VII. Schiaparelli, 1881.
(From Schiaparelli's *Memoria.*)



Map VIII. Schiaparelli, 1884.
(From Schiaparelli's *Memoria.*)

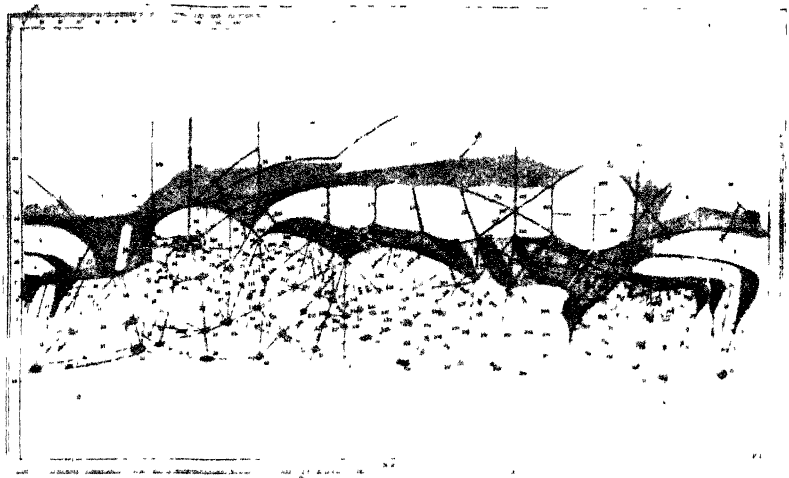
Books it increased with putting off. What he offered the public in 1879 was much more dearly to be bought. The lines were straighter, narrower, and in every way less natural than they had seemed two years before. In 1881–1882 they progressed still more in unaccountability. They had now become regular rule and compass lines, as straight, as even, and as precise as any draughtsman could wish and quite what astronomic faith did not desire. Having thus donned the character, they nevermore put it off.

Now, this curious evolution in depiction points, rightly viewed, to an absence of design. It shows that Schiaparelli started with no preconceived idea on the subject. On the contrary, it is clear that he shared to begin with the prevailing hesitancy to accept anything out of the ordinary. Nor did he overcome his reluctance except as by degrees he was compelled. For the canals did not change their characteristics from one opposition to another; the eye it was that learned to distinguish what it saw, and the brain made better report as it grew familiar with the messages sent it. In other words, it is patent from these successive maps that the geometrical character of the 'canals' was forced upon Schiaparelli by the things themselves, instead of being, as his critics took for granted, foisted on them by him. We have since seen the regularity of the canals so undeniably that we are not now in need

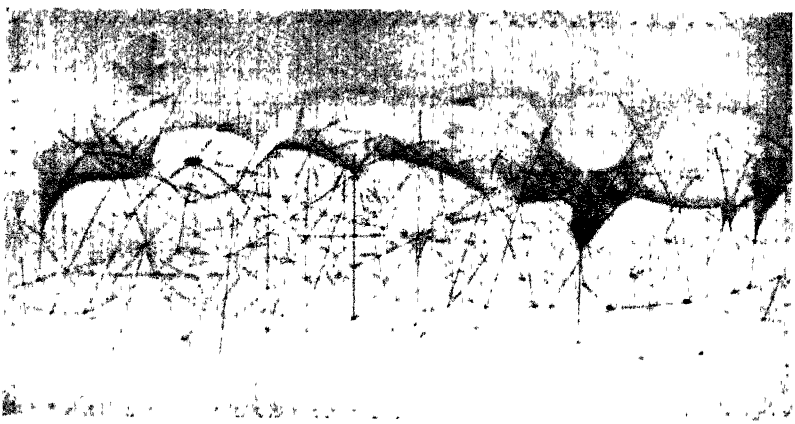
of such inferential support to help us to the truth; but too late, as it is, to be of controversial moment the deduction is none the less of some corroboratory force.

With the third period enters what has been done since Schiaparelli's time. For that master was obliged, from failing sight, to close his work with the opposition of 1890. In 1892 W. H. Pickering at Arequipa was the chief observer of the planet and made two important discoveries: one was the detection of small round spots scattered over the surface of the planet and connected with the canal system; the other the perception of what seemed to him more or less irregular lines traversing the Mare Erythraeum. Both were notable detections. The first set of phenomena he called lakes, the second river-systems, sometimes schematically 'canals,' but without committing himself to canaliform characteristics as his drawings make clear. The same phenomena were seen at that opposition at the Lick, by Schaeberle, Barnard and others, and called streaks. These discoveries took from the *maria* their supposed character of seas — a most important event in knowledge of Mars.

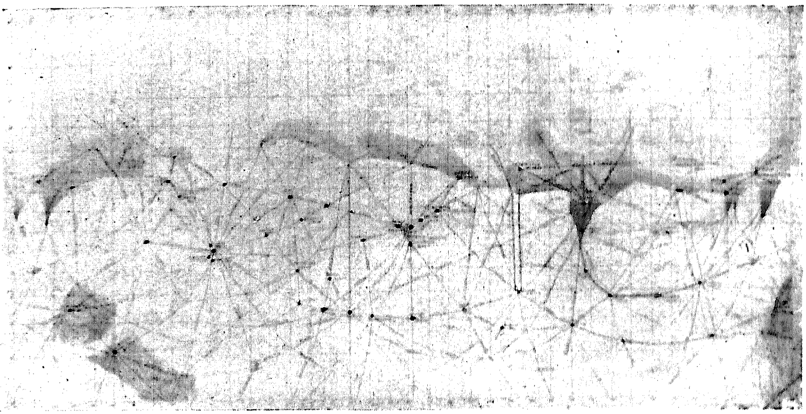
The next advance was the detection at Flagstaff in 1894 of their canaliform characteristics by my then assistant Mr. Douglass, who in place of the irregular streaks and river-systems of his predecessors found the seas to be crossed by lines as regular and



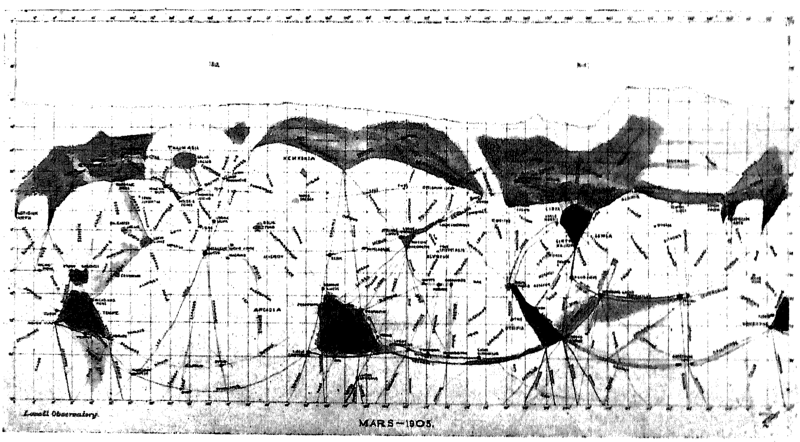
Map IX. Lowell, 1894.



Map X. Lowell, 1896.



Map XI. Lowell, 1901.



Map XII. Lowell, 1905.

as regularly connected as the canals in the light regions. To him they appeared broad and ill defined, but so habitually did to him the canals in the light areas, while for directness and uniformity the one set showed as geometrically perfect as the other. All the dark *maria* of the southern hemisphere he found to be laced with them and that they formed a network over the dark regions, counterparting that over the light. Still more significant was the fact that their points of departure coincided with the points of arrival of the bright-region canals, so that the two connected to form in its entirety a single system. After the publication of his results (Lowell Observatory Annals, Volume I, 1895) Schiaparelli identified some of those in the Syrtis with what he had himself seen there in 1888 (*Memoria*, VI, 1899), though his own had not been sufficiently well seen of him to impress him as canals.

Of other additions to our knowledge since made by the writer the present book treats; as also of the theory they originally suggested to him and which his later observations have only gone to confirm.

CHAPTER IV

THE POLAR CAPS

ALMOST as soon as magnification gives Mars a disk that disk shows markings, white spots crowning a globe spread with blue-green patches on an orange ground. The smallest telescope is capable of this far-off revelation; while with increased power the picture grows steadily more articulate and full. With a two and a quarter inch glass the writer saw them thirty-five years ago.

After the assurance that markings exist the next thing to arrest attention is that these markings move. The patches of color first made out by the observer are shortly found by him to have shifted in place upon the planet. And this not through mistake on his part but through method in the phenomena; for all do it alike. In orderly rotation the features make their appearance upon the body's righthand limb (in the telescopic image), travel across the central meridian of the disk and vanish over its lefthand border. One follows another, each rising, culminating and setting in its turn under the observer's gaze. A constantly progressing panorama passes majestically before his sight, new

objects replacing the old with a march so steady and withal so swift that a few minutes will suffice to mark unmistakably the fact of such procession. But for all this ceaseless turning under his gaze, after a certain lapse of time it is evident that the same features are being shown him over again. With such recognition of recurrence comes the first advance toward acquaintance with the Martian world. For that in all their journeying their configuration alters not, proves them permanent in place, part and parcel of the solid surface of that other globe. This surface, then, lies exposed to view and by its turning shows itself subject, like our earth, to the vicissitudes of day and night.

In such self-exposure Mars differs from all the four great planets, Jupiter, Saturn, Uranus and Neptune. Features, indeed, are apparent on the first two of these globes and dimly on the other two as well, but they lack the stability of the Martian markings. They are forever exchanging place. In the case of Jupiter what we see is undoubtedly a cloud-envelop through which occasional glimpses may possibly be caught of a chaotic nucleus below. With Saturn it is the same; and the evidence is that the like is true of Uranus and Neptune. What goes on under their great cloud canopies we can only surmise. With Mars, however, we are not left to imagination in the matter but so far as our means permit can actually observe what there takes place. Except for

distance, which, through science, year by year grows less, it is as if we hovered above the planet in a balloon, with its various features spread out to our gaze below.

Attention shows these areographic features to be on hand with punctual precision for their traverse of the disk once every twenty-four hours and thirty-seven minutes. For over two hundred years this has been the case, their untiring revolutions having been watched so well that we know the time they take to the nicety of a couple of hundredths of a second. We thus become possessed of a knowledge of the length of the Martian day and it is not a little interesting to find that it very closely counterparts in duration our own, being only one thirty-fifth the longer of the two. We also find from the course the markings pursue the axis about which they turn; and just as the period of the rotation tells us the length of the Martian day so the tilt of the axis, taken in connection with the form of the orbit, determines the character of the Martian seasons. Here again we confront a curious resemblance in the circumstances of the two planets, for the tilt of the equator to the plane of the orbit is with Mars almost precisely what it is for the Earth. The more carefully the two are measured the closer the similitude becomes. Sir William Herschel made the Martian 28°, Schiaparelli reduced this to 25°, and later determination by the writer

puts it nearer 24°. The latter is the one now adopted in the British Nautical Almanac for observers of the planet. This is a very close parallelism indeed; so that in general character the Martian seasons are nearly the counterpart of ours. In length, however, they differ; first because the year of Mars is almost double the length of the terrestrial one and secondly because from the greater ellipticity of Mars' orbit the seasons are more unequal than is the case with us, some being run through with great haste, others being lingered on a disproportionate time. It is usual on the Earth to consider spring as the period from the vernal equinox, about March 21, to the summer solstice, about June 20; summer as lasting thence to the autumnal equinox; autumn from this latter date, about September 20, to the winter solstice on December 21; and winter from that point on to the next spring equinox again. On this division our seasons in the northern hemisphere last respectively: spring, 91 days; summer, 92 days; autumn, 92 days; and winter, 90 days. On Mars these become, reckoned in our days: spring, 199 days; summer 183 days; autumn, 147 days; and winter, 158 days. If we had counted them in Martian days they would have totaled about one thirty-fifth less in number each.

In its days and seasons, then, Mars is wonderfully like the Earth; except for the length of the year we

should hardly know the difference in reckoning of time could we some morning wake up there instead of here. Only in one really unimportant respect should we feel strange; in months we should find ourselves turned topsy-turvy. But lunations have nothing to do with climate nor with the alternation between night and day; and in these two important respects we should certainly feel at home.

Though the axis could be determined by the daily march of any marking and thus the planet's tropic, temperate and polar regions marked out, the process is made easier by the presence of white patches covering the planet's poles and known, in consequence, as the polar caps. It is from measures of the patches that the position of the Martian poles has actually been determined. These polar caps are exactly analogous in general position to those which bonnet our own Earth. They reproduce the appearance of the ice and snow of our arctic and antarctic regions seen from space, in a very remarkable manner. In truth they are things of note in more ways than one and would claim precedence on many counts. Priority of recognition, however, alone entitles them to premier consideration. Among the very first of the disk's detail to be made out by man, they justly demand description first.

With peculiar propriety the polar caps have thus the *pas*. Not only do they stand first in order of

visibility, but they prove to occupy a like position logically when it comes to an explanation of the planet's present physical state. It is not matter of hazard that the most evident of all the planet's markings should also be the most fundamental, the fountainhead from which everything else flows. It is of the essence of the planet's condition and furnishes the key to its comprehension. The steps leading to this conclusion are as interesting as they are cogent. They start at the polar caps' visibility. For their size first riveted man's attention and then attention to them disclosed that most vital of the characteristics of the planet's surface: change.

Just as almost all of the features we note are permanent in place, showing that they belong to the surface, so are they all impermanent in character. Change is the only absolutely unchanging thing except position about the features the planet presents to view. It was in the aspect of the polar caps that this important fact first came to light. Not only did they thus initially instance a general law, they have turned out to make it; for by themselves changing they largely cause change in all the rest. But for a long time they alone exemplified its workings. To Sir William Herschel we owe the first study of their change in aspect. This eminent observer noted that their varying size was subject to a regular rhythmic wax and wane timed to

the course of the seasons of the planet's year. The caps increased in the winter of their hemisphere and decreased in its summer and being situate in opposite hemispheres they did this alternately with pendulum-like precision. His observations were soon abundantly confirmed, for the phenomena take place upon a vast scale and are thus easy of recognition. At their maximum spread the caps cover more than one hundred times as much ground as when they have shrunk to their minimum. In the depth of winter they stretch over much more than the polar zone, coming down to 60° and even 50° of latitude north or south as the case may be, thence melting till by midsummer they span only five or six degrees across.

In this they bear close analogue to the behavior of our own. Ours would show not otherwise were they viewed from the impersonal standpoint of space. Very little telescopic aid suffices to disclose the Martian polar phenomena in this their more salient characteristics and convince an observer of their likeness to those of the earth. Any one may note what is there going on by successive observations of the planet with a three-inch glass. Nor is the change by any means slow. A few days at the proper Martian season, or at most a couple of weeks, produces conspicuous and conclusive alterations in the size of these nightcaps of the planet's winter sleep. Resembling our own so well they were

early surmised to be of like constitution and composed, therefore, of ice and snow. Plausible on its face, this view of them was generally adopted and common sense has held to it ever since. It has encountered, of course, opposition, partly from very proper conservatism, but chiefly from that earth-centred philosophy which has doubted most advances since Galileo's time, and carbonic acid has been put forward by this school of sceptics to take its place. We shall critically examine both objections; the latter first, because a certain physical fact enables us to dispose of it at once. In casual appearance there is not much to choose between the rival candidates of common sense and uncommon subtlety, water and frozen carbonic acid gas, both being suitably white and both going and coming with the temperature. But, upon closer study, in one point of behavior the two substances act quite unlike, and had half the ingenuity been expended in testing the theory as in broaching it this fact had come to light to the suggestors as it did upon examination to the writer and had served as a touchstone in the case. At pressures of anything like one atmosphere or less carbonic acid passes at once from the solid to the gaseous state. Water, on the other hand, lingers in the intermediate stage of a liquid. Now, as the Martian cap melts it shows surrounded by a deep blue band which accompanies it in its retreat, shrinking to keep pace with the

shrinkage in the cap. This is clearly the product of the disintegration since it waits so studiously upon it. The substance composing the cap, then, does not pass instantaneously or anything like it from the solid to the gaseous condition.

This badge of blue ribbon about the melting cap, therefore, conclusively shows that carbonic acid is not what we see and leaves us with the only alternative we know of: water.

CHAPTER V

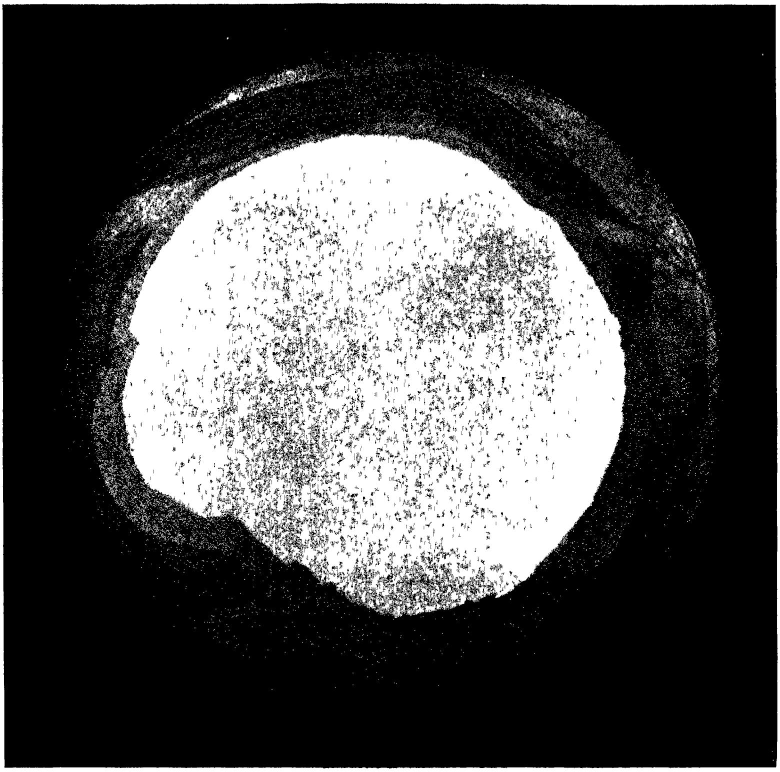
BEHAVIOR OF THE POLAR CAPS

ASSURED by physical properties that our visual appearances are quite capable of being what they seem we pass to the phenomena of the cap itself. Like as are the polar caps of the two planets at first regard, upon further study very notable differences soon disclose themselves between the earthly and the Martian ones; and these serve to give us our initial hint of a different state of things over there from that with which we are conversant on Earth.

To begin with, the limits between which they fluctuate are out of all proportion greater on Mars. It is not so much in their maxima that the ice-sheets of the two planets vary. Our own polar caps are much larger than we think; indeed, we live in them a good fraction of the time. Our winter snows are in truth nothing but part and parcel of the polar cap at that season. Now, in the northern hemisphere snow covers the ground at sea-level more or less continuously down to 50° of latitude. It stretches thus far even on the western flanks of the continents, while in the middle of them and on their eastern sides it extends ten degrees

farther yet during the depth of winter. So that we have a polar cap which is then ninety degrees across. In our southern hemisphere it is much the same six months later, in the corresponding winter of its year.

On Mars at their winter maxima the polar caps extend over a similar stretch of latitude. They do so, however, unequally. The southern one is considerably the larger. In 1903, 136 days after the winter solstice, in the Martian calendar February 27, it came down in longitude 225° to 44° of latitude and may be taken to have then measured ninety-three degrees across; in 1905, 121 days after the same solstice, it stretched in longitude 235° to latitude 42°, and 158 days later, in longitude 221° to latitude 41°; values which, supposing it to have been round, imply for it a diameter on these occasions of ninety-six and ninety-seven degrees. It was then February 20 and March 10 respectively of the Martian year. These determinations of its size at the two oppositions agree sufficiently well considering the great tilt away from us of the south pole at the time and the horizonward foreshortening of the edge of the snow. It seems from a consensus of the measures to have been some five degrees wider in 1903 than in 1905, which may mean a colder winter preceding the former date. The cap was still apparently without a dark contour in both years, showing that it had not yet begun to melt.



South Polar Cap
(Lowell Observatory, 1905.)

useful as shorthand to the cult, becomes meaningless jargon to the uninitiate and is paraded most by the least profound. But worse still for their employ symbols tend to fictitious understanding. Formulæ are the anæsthetics of thought, not its stimulants; and to make any one think is far better worth while than cramming him with ill-considered, and therefore indigestible, learning.

Even to the technical student, a popular book, if well done, may yield most valuable results. For nothing in any branch of science is so little known as its articulation, — how the skeleton of it is put together, and what may be the mode of attachment of its muscles.

PERCIVAL LOWELL.

Oak Creek, Arizona,
June 1, 1906.

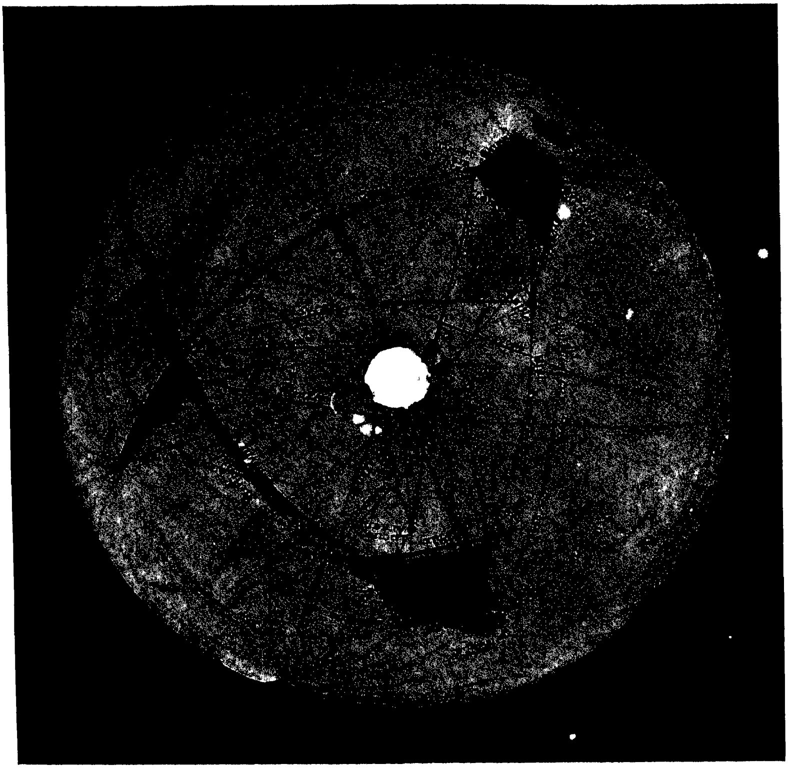
Less has been learnt of the northern cap. In 1896–1897 when it was similarly presented skirting the other rim of the disk, a gap occurred in the observations corresponding to the time by Martian months between February 24 and March 22. On the former date the cap came down only to latitude 55° in longitude 352°; on the subsequent one and for several days after the latitude of the southern limit of the snow was such as to imply a breadth to it of about eighty degrees. The cap was now bordered by a dark line, proving that melting had already set in. It cannot, however, at its maximum have covered much more country than this, in view of its lesser extent on February 24.

Fair as our knowledge now is of the dimensions of the Martian polar caps at their maxima, we have much more accurate information with regard to their minima, and this, too, was obtained much earlier. That we should first have known their smallest rather than their greatest extent with accuracy may appear surprising, exactly the opposite being our knowledge of our own. It is not, however, so surprising as it appears, inasmuch as it is an inevitable consequence of the planet's aspect with regard to the sun. When the tilt of the axis inclines one hemisphere toward the sun, that hemisphere's polar cap must melt and dwindle, while at the same time it is the one best seen, the other being turned away from the sun and therefore largely

from us as well; so that even such part of the latter as is illumined lies low down toward the horizon of the disk where a slight change of angle means a great difference in size.

It has thus come about that both the south and the north polar caps have been repeatedly well seen and measured at their minimum; and the measures for different Martian years agree well with one another. For the northern cap six degrees in diameter is about the least value to which it shrinks. The south one becomes even smaller, being usually not more than five degrees across, while in 1894 it actually vanished, a thing unprecedented. Its absence was detected by Douglass at Flagstaff and shortly after the announcement of its disappearance the fact was corroborated by Barnard at the Lick. The position the cap would have occupied was at the time better placed for observation in America than in Europe, inasmuch as the cap is eccentrically situated with regard to the geographic pole and its centre was then well on the side of the disk presented to us while in Europe it was turned away. This, together with the fact that it undoubtedly came and went more than once about this time, accounts for its disappearance not having been recognized there, haze left by it having apparently been mistaken for the cap itself.

On Earth the minima are much larger. In the



North Polar Cap.
(Lowell Observatory, 1905.)

northern hemisphere the line of perpetual snow or pack-ice in longitude 50° east runs about on the 80° parallel, including within it the southern end of Franz Joseph Land. Opposite this, in longitude 120° west, above the North American continent, it reaches down lower still to 75°. So that the cap is then from twenty to thirty degrees in diameter. In the southern hemisphere it is even larger. In longitude 170° west the land was found by Ross to be under perpetual snow in latitude 72°. Cook had reached in longitude 107° east an impassable barrier of ice in latitude 70° 23′. The season was then midsummer, January 30. So that we are perhaps justified in considering 71° south as about the average limit of perpetual snow or paleocrystic ice. This would make the southern cap at its minimum thirty-eight degrees across. Pack-ice with open spots extends still farther north. The Pagoda in 1845 was stopped by impenetrable pack-ice in south latitude 68° and the Challenger in 1874 encountered the pack in latitude 65° on the 19th of February, which corresponds about to our 19th of August, the time at which the sea should be most open. The limit of perpetual snow is thus lower in the southern than in the northern hemisphere. Here again, then, the two minima differ, but in the reverse way from what they do on Mars.

From this we perceive that the variations in size of

the caps are much more striking on Mars than on the Earth and that these are due chiefly to the difference in the minima, the maxima not varying greatly.

To explain these interesting diversities of behavior in the several polar caps we shall have to go back a little in general physics in order to get a proper take off. It is a curious concomitant of the law of gravity that the amount of heat received by a planet in passing from any point of its path to a point diametrically opposite is always the same no matter what be the eccentricity of the orbit. Thus, a planet has as many calories falling upon it in travelling from its vernal equinox to its autumnal as from the autumnal to the vernal again, although the time taken in the one journey be very different from that of the other. This is due to the fact that the angle swept over by the radius vector, that is, the imaginary bond between it and the sun, is at all points proportional to the amount of heat received; just as it is of the gravity undergone, the two forces radiating into space as the inverse square of the distance. Thus the heat received by a point or a hemisphere, through any orbital angle, is independent of the eccentricity of the orbit.

But it is not independent of the axial tilt. For the force of the sun's rays is modified by their obliquity. The amount of heat received at any point in consequence of the tilt turns upon the position of the point, and for

any hemisphere taken as a whole it depends upon the degree to which the pole is tilted to the source of heat. In consequence of being more squarely presented to its beams, the hemisphere which is directed toward the sun and therefore is passing through its summer season gets far more insolation than that which is at the same time in the depth of its winter. For a tilt of twenty-four degrees, the present received value for the axis of Mars, the two hemispheres so circumstanced get amounts of heat respectively in the proportion of sixty-three to thirty-seven.

But, though the summer and winter insolation thus differ, they are the same for each hemisphere in turn. Consequently the mere amount of heat received cannot be the cause of any differences detected between the respective maxima and minima of the two polar caps. If heat were a substance which could be stored up instead of being a mode of motion, the effect produced would be in accordance with the quantity applied and the two caps would behave alike. As it is the total amount has very little to say in the matter.

Not the amount of heat but the manner in which this heat is made at home is responsible for the difference we observe. Now, though the total amount is the same in passing from the vernal to the autumnal equinox as from the autumnal to the vernal, the time during which it is received in either case varies from one hemi-

sphere to the other. It is summer in the former while it is winter in the latter and the difference in the length of the two seasons due to the eccentricity of the orbit makes a vast difference in the result. Winter affects the maxima, summer the minima, attained. Of these opposite variations presented to us by the two caps, the maxima, the one most difficult to detect, is the easiest to explain, for the difference in the maxima seems to be due to the surpassing length of the antarctic night.

Owing to the eccentricity of the orbital ellipse pursued by Mars and to the present position of the planet's solstices, the southern hemisphere is farther away from the sun during its winter and is so for a longer time. The seasons are in length, for the northern hemisphere: spring, 199 days; summer, 183 days; autumn, 147 days; and winter, 158 days; while for the southern hemisphere they are: spring, 147 days; summer, 158 days; autumn, 199 days; and winter, 183 days. The arctic polar night is thus 305 of our days long; the antarctic, 382. Thus for 77 more days than happens to its fellow the southern pole never sees the sun. Now, since the total sunlight from equinox to equinox is the same in both hemispheres, its distribution by days must be different. In the southern hemisphere the same amount is crowded into a smaller compass in the proportion of 305 to 382; that being that hemisphere's

relative ratio of days. But since during winter the cap increases, there is a daily excess of accumulation over dissipation of snow and each twenty-four hours must on the average add its tithe to the sum total. Since the northern days are the warmer each adds less than do the southern ones; and furthermore there are fewer of them. On both these scores the amount of the deposition about the northern pole should be less than about the southern one. Consequently, the snow-sheet there should be the less extensive and show a relatively smaller maximum, which explains what we see.

With the minima the action is otherwise. Inasmuch as the greater heat received during the daylight hours by the southern hemisphere is exactly offset by the shortness of its season, it would seem at first as if there could be no difference in the total effect upon the two ice-caps.

But further consideration discloses a couple of factors which might, and possibly do, come in to qualify the action and account for the observed effect. One is that though the total amount of heat received is the same, the manner of its distribution differs in the two hemispheres. In the northern one the time from vernal to autumnal equinox is 382 days against 305 in the southern. Consequently, the average daily heat is then five fourths more intense in the southern hemi-

sphere. Indeed, it is even greater than this and nearer four thirds, because the melting occurs chiefly in the spring and in the first two months of summer when the contrast in length of season between the two hemispheres is at its greatest. Now, a few hotter days might well work more result than many colder ones. And this would be particularly true of Mars where the mean temperature is probably none too much above the freezing-point to start with. Ice consumes so much caloric in the process of turning into any other state, laying it by in the form of latent heat before it can turn into water and then so much more before this water can be converted into steam that a good deal has to be expended on it before getting any perceptible result. Once obtained, however, the heat is retained with like tenacity. So that the process works to double effect! If sufficient heat be received the ice is first melted, then evaporated and finally formed into a layer of humid air, the humidity of which keeps it warm. Dry air is unretentive of heat, moist air the opposite. And for the melting of the ice-cap to proceed most effectively the temperature that laps it about must be as high as possible and kept so as continuously as may be. If between days it be allowed to fall too low at night much caloric must needs be wasted in simply raising the ice again to the melting-point. This a blanket of warm air tends to prevent, and this again

is brought about by a few hot days rather than by many colder ones. It is not all the heat received that becomes effective but the surplus heat above a certain point. The gain in continuity of action thus brought about is somewhat like that exhibited between the running of an express and an accommodation train. To reach its destination in a given time the former requires far less power because it does not have to get up speed again after each arrest. Thus the whole effect in melting the snow would be greater upon that hemisphere whose summer happens to be the more intense.

The greater swing in size of the cap most exposed to the effects of the eccentricity is, then, the necessary result of circumstances when the precipitation is not too great to be nearly carried off by the subsequent dissipation. This is the state of things on Mars and the second of the factors above referred to. On the Earth as we have seen the polar caps are somewhat larger at their maximum and very much so at their minimum. Now, this is just what should happen were the precipitation increased. Suppose, for example, that the amount of precipitation were to increase while the amount of summer melting remained the same, and this would be the case if the vapor in the air augmented for one cause or another, and the result of each fresh deposit was locked up in snow. After a certain point the cap would grow in depth rather than

in extension; the winter deposit would be thicker but the summer evaporation would remain the same. Now, if this occurred, it is evident that the minimum size of the cap would increase relatively much faster than the maximum, and furthermore, that the relative increase of the minimum in the two caps would be greatest for that which had seasons of extremes. The result we see in the case of the Earth. In the arctic cap, where in consequence of the eccentricity of the orbit the winter is shorter, the maximum is less than in the antarctic and this extra amount of precipitation cannot be wholly done away with in its intenser summer, so that the minimum too is greater there.

We reach, then, this interesting conclusion. We find that eccentricity of orbit by itself not only causes no universal glaciation in the hemisphere which we should incidentally suppose likely to show it, but actually produces the opposite result, in more than offsetting by summer proximity what winter distance brings about. To cause extensive glaciation we must have, in addition to favorable eccentricity, a large precipitation. With these two factors combined we get an ice age, but not otherwise. The result has an important bearing on geologic glacial periods and their explanation.

Once formed, an ice-sheet cools everything about it and chills the climate of its hemisphere. It is a perpetual storehouse of cold. Mars has no such general

glaciation in either hemisphere, and the absence of it, which is due to lesser precipitation, together with the clearness of its skies, accounts for the warmth which the surface exhibits and which has been found so hard hitherto to interpret. Could our earth but get rid of its oceans, we too might have temperate regions stretching to the poles.

CHAPTER VI

MARTIAN POLAR EXPEDITIONS

POLAR expeditions exert an extreme attraction on certain minds, perhaps because they combine the maximum of hardship with the minimum of headway. Inconclusiveness certainly enables them to be constantly renewed, without loss either of purpose or prestige. The fact that the pole has never been trod by man constitutes the lodestone to such undertakings; and that it continues to defy him only whets his endeavor the more. Except for the demonstration of the polar drift-current conceived of and then verified by Nansen, very little has been added by them to our knowledge of the globe. Nor is there specific reason to suppose that what they might add would be particularly vital. Nothing out of the way is suspected of the pole beyond the simple fact of being so positioned. Yet for their patent inconclusion they continue to be sent in sublime superiority to failure.

Martian polar expeditions, as undertaken by the astronomer, are the antipodes of these pleasingly perilous excursions in three important regards, which if less appealing to the gallery commend themselves to the

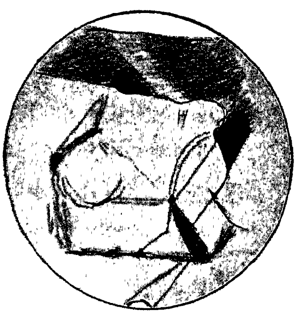
philosopher. They involve comparatively little hardship; they have accomplished what they set out to do; and the knowledge they have gleaned has proved fundamental to an understanding of the present physical condition of the planet.

The antithesis in pole-pursuing between the two planets manifests itself at the threshold of the inquiry, in the relative feasibility with which the phenomena on Mars may be scanned. For, curiously enough, instead of being the pole and its surrounding paleocrystic ice which remains hidden on Mars, it is rather the extreme extent of its extension and the lowest latitudinal deposit of frost which lies shrouded in mystery. The difficulty there is not to see the pole but to see in winter the regions from which our own expeditions set out. And this because the poles are well displayed to us at times which are neither few nor very far between; while favorable occasions for marking the edge of the caps when at their greatest have neither proved so numerous nor so favorable. The tilt of the planet's axis when conveniently placed for human observation has been the cause of the one drawback; the planet's meteorological condition in those latitudes at that season the reason for the other.

What knowledge we have of the size of the caps in degrees upon the surface of the planet at this their extreme equatorward extension has been given in the

last chapter. Their aspect at the time together with what that aspect betokens was not there touched upon. With it, therefore, and the peculiarities it presents to view we shall begin our account of the caps' annual history.

When first the hemisphere, the pole of which has for half a Martian year been turned away from the sun, begins to emerge from its long hibernation, the snow-cap which covers it down even to temperate regions presents an undelimited expanse of white, the edges of which merge indistinguishably into the groundwork color of the regions round about. Of a dull opaque hue along its border, its contour is not sharp but fades off in a fleecy fringe without hard and fast line of demarcation. Such notably was the aspect of the north temperate zone in 1896 when, tilted as it then was away from us into a mere northern horizon of the planet's limb, it showed prior to the definite recognition of the north polar cap in August of that year, and such too was the look of the disk's southern edge both before and after the first certain detection of the southern cap in 1903 and 1905. Each was then in the depth of winter. For in Martian chronology the season cor-



South Polar Cap in winter.

responded in each at the time to what we know in our northern hemisphere as the latter part of February and the early part of March and the appearance of the planet's surface in both was not unlike what we know at the same season in latitude 45°. Indeed, there is reason to suppose bad weather there then and the extreme fringe, from the pale tint it exhibited, to have been cloud rather than snow.

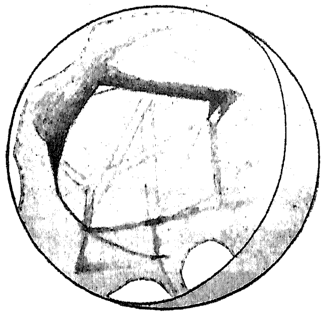
It is quite in keeping with what we know on earth or can conceive of elsewhere that such aspect should characterize the cap at or near the attainment of its greatest development. Whether it were not yet quite arrived at this turning-point of its career or had but slightly passed it a vagueness of outline would in either event proclaim the fact. For were the frost still depositing, the cap's edge would show indefinite; and on the other hand had it just begun to melt, evaporation would give it an undefined edge before the melting water had gathered in sufficient quantities to be itself noticeable.

Its behavior subsequent to recognition bore out the inference from its aspect when it first appeared. While for many days prior to its coming unmistakably into view it was impossible to say whether what was seen of the southern cap in 1903 and 1905 was cloud or snow; so even after it had definitely disclosed itself it continued to play at odds with the observer. Showing

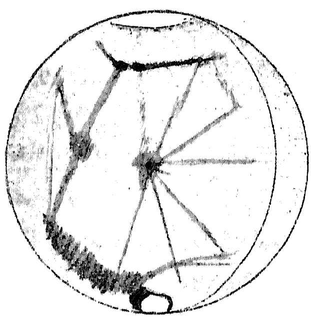
sharp at the edges one day it would appear but hazily defined the next, thus clearly demonstrating itself to be at the then unstable acme of its spread. Such a state of things we are only too familiar with in our own March weather when after days of sunshine that have melted off the winter's white and fringed it with rivulets and awakening grass, a snow-storm falling upon it powders the ground again that was beginning to be bare and at one stroke extends the domain of the snow while mystifying the actual limits it may be said to occupy. The same condition of things, then, is not unknown on Mars, and to fix the precise date of so wavering a phenomenon is not so much matter of difficult observation as of physical impossibility.

Nor is the southern cap, at this the height of its winter expansion, confined strictly to its own proper limits. Faint extensions, now so connected with its main body as to form part and parcel of it, now so detached and dull of tint as to make the observer doubtful of the exact relationship, are generally to be seen attendant on it. Hellas in winter is much given to such questionable garb, and has in consequence been mistaken by more than one observer for the cap itself, appearing as it does well upon the southern limb and being often the only region to show white. Indeed, frost-bound as it then is, to consider it the polar cap, though possibly geographically incorrect, may cli-

matologically be sustainable. Its northern extremity extends down to latitude 30°, a pretty low latitude for frost. Still such equatorward extension is not without corroborating parallel. In 1903, at what was in Martian dates April 26, the whole of the region south of the Solis Lacus and the Nectar showed white, with a whiteness which may as well have been hoarfrost as cloud. Now, the Nectar runs east and west in latitude 28°. So that in this instance, too, it is possible that arctic conditions knocked at the very doors of the tropics. Encroachment of the sort is equivalent to snow in Cairo and permanent snow at that; not an occasional snow flurry, but something to linger on the ground and stay visible sixty millions of miles away.



Hellas in winter.



White south of Nectar and Solis Lacus.

Knowledge of either cap in this the midwinter of its year has been a matter of the most recent oppositions of the planet. Up to within the last few years our acquaintance with either cap was chiefly confined to the

months, — one might almost say the weeks, — immediately surrounding the summer solstice of its respective hemisphere. The behavior of the caps during the rest of their career was largely unknown to us, from the very disadvantageous positions they occupied at the times the planet was nearest to the earth. Beginning with 1894, however, our knowledge of both has been much extended, by a proportionate extension of the period covered by the observations. It used to be thought impracticable to observe the planet far on either side of opposition; now it is observed from as much as four months before that event to the same period after it. The result is a systematic series of observations which in many ways has given unexpected insight into Martian conditions. One of the benefits secured has been the lengthening of the period of study of the cap's career, a pushing of inquiry farther back into its spring history and a longer lingering with it in its autumnal rebuilding. Yet up to the very last opposition a gap in its chronology still remained between February 25 and April 1. The opposition of 1905 has bridged this hiatus and brought us down to the latter date, at which the melting of the cap begins in earnest.

From this point, April 1 on, we have abundant evidence of the cap's behavior. Its career now for some time is one long chronicle of contraction. Like Bal-

zac's *Peau de Chagrin* it simply shrinks, giving out of its virtue in the process. The cap proceeds to dwindle almost under the observer's eye till, from an enormous white counterpane spread over all the polar and a large part of the temperate zone, its area contracts to but the veriest nightcap of what it was before. From seventy degrees across it becomes sixty, then fifty, then forty, till by the middle of the Martian May it has become not more than thirty degrees in diameter. During this time, from the moment the melting began in good earnest, the retreating white is girdled by a dark band, of a blue tint, which keeps pace with the edge of the cap, shrinking as it shrinks, and diminishing in width as the volume of the melting decreases.

After the melting has been for some time under way and the cap has become permanently bordered by its dark blue band a peculiar phenomenon makes its appearance in the cap itself. This is its fission into one or more parts. The process begins by the appearance of dark rifts which, starting in from the cap's exterior, penetrate into its heart until at last they cleave it in two. Rifts have been seen by several observers and in both caps; and what is most suggestive they always appear in the same places, year after year. Sometimes oppositions elapse between their several detections for they are not the least difficult of detail; but when

they are caught, they prove to lie just where they did before.

The permanency in place of the rifts, a characteristic true of them all, shows them to be of local habit. Thus the rift of 1884 and 1897 reappeared again to another observer in the same position in 1901. They are, therefore, features of, or directly dependent on, the surface of the planet. But it will not do from this fact to infer that they are expressive of depressions there. The evidence is conclusive that great irregularities of surface do not exist on Mars. As we shall see when we come to consider the orology of the planet it is certain that elevations there of over two or three thousand feet in altitude are absent. Differences of temperature, able to explain a melting of the ice in one locality coincidentally with its retention in an adjacent one, must in consequence be unknown. And this much more conclusively than at first appears, for the reason that the smaller the planet's mass the less rapidly does its blanket of air thin out in ascent above the surface. This is in consequence of the greater pull the larger body exerts and the greater density it imparts to a compressible gas like our atmosphere. Gravity acts like any force producing pressure and by it the envelope of air is squeezed into a smaller compass. But as this is done throughout the atmospheric layer it means a more rapid rarefaction as one leaves the body. The

action is such that the height necessary to reach an analogic density varies inversely as the gravity of the mass. In consequence of this, to compass a relative thermometric fall for which a moderate difference of elevation would suffice on Earth, an immoderate one must be made on Mars. For gravity there being but three eighths what it is here, eight thirds the rise must be made to attain a proportionate lowering of temperature. This fact renders the above argument against elevation and depression being the cause of the phenomenon three times as cogent as it otherwise would be.

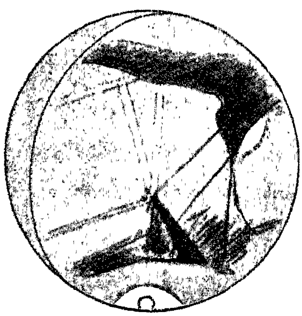
With so gradual a gradient in barometric pressure there and so low a set of contour lines, altitude must be a negligible factor in Martian surface meteorologic phenomena. Both density and temperature can be but little affected by such cause, and we must search elsewhere for explanation of what surface peculiarities we detect.

Meanwhile the rifts themselves, from being lines which penetrate the cap from its periphery in toward its centre, end by traversing it in its entirety and separating portions which, becoming outlying subsidiary patches, themselves proceed to dwindle and eventually disappear. The rifts usually take their rise from such broader parts of the cap-encircling blue belt as make beads upon that cordon and are clearly spots where the

product of the melting of the cap is either specially collected, or produces its most visible effect.

So far the description might apply with substantial accuracy to either cap. Yet the conduct of the two is in some ways diverse and begins to accentuate itself from this point on.

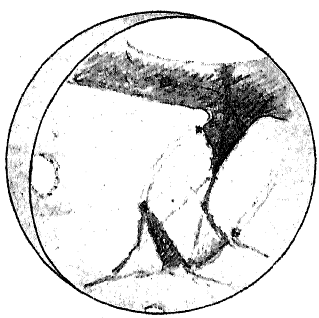
From the time that the north polar cap reaches a diameter of about twenty-five degrees, a singular change steals over it. From having been up to then of a well-defined outline it now proceeds to grow hazy and indistinct all along its edge. This change in its character at the same period of its career has been quite noticeable at each of the three last oppositions, so that small doubt remains that the metamorphosis is a regularly recurrent one in the history of the cap. Coincident with the obliteration of its contour, its dimensions seemingly enlarge. It is as if a hood had been drawn over the cap of a dull white different from the dazzling brilliance of the cap itself and covering more ground. Such is probably what occurs; with vapor for veil. The excessive melting of the cap produces an extensive evaporation which then in part condenses to be deposited afresh, in part re-



Northern Cap hooded with vapor.

mains as a covering, shutting off from our view the outlines of the cap itself. It would seem that at this time the cap melts faster than the air can carry it off. A sort of steaming appears to be going on, taking place *in situ.* For it clearly is not wafted away. The time of its coming too is significant. For the season is May 15, the height of time for a spring haze to set in. Then later it dissipates with the same quiet indefiniteness with which it gathered.

It is some time in Martian June before the spring haze clears away, and when it does go, only a tiny polar cap stands revealed beneath it, from six to eight degrees across, or from a tenth to a fifteenth of what it was when it passed into its curious spring chrysalis. The date of emergence varies. In 1903 it occurred early, the haze not being marked after June 3, though recurring again at intervals for a day or so. In 1905 it was later; perceptibly thin after June 21 it did not certainly clear away till June 9 and came back again on July 16 and possibly on the 25th.



Northern Cap unmasked.

These vicissitudes of aspect give us glimpses into a sweet unreasonableness in Martian weather which

makes it seem more akin to our own. And this on two counts, diurnal and annual. From day to day atmospheric conditions shift for purely local cause; while, furthermore, successive Martian years are not alike. In some the season is early; in others late. So that Mars is no more exempt than are we from the wantonness of weather.

Clearly disclosed thus reduced to its smallest possible terms it remains for some months of our days, for six weeks of its own. During that period it continues practically unchanged, neither increasing nor decreasing significantly in size, nor altering notably in aspect. Measures of the drawings of it then make it from five to eight degrees across and it is possible that it really fluctuates between narrow limits, though its clear-cut outline at all times renders the variation difficult to explain. We are not so near it as we could wish; for on these occasions even at their best it is over two hundred times as distant as the moon and the greatest magnification possible still leaves it a hundred thousand miles away.

To the south polar cap a somewhat similar history attaches, but with a difference. In its case no such regularly recurrent spring haze has yet been noted. The melting of this cap would seem to be of a more orderly nature than its fellow and not to outdo what can conveniently be carried off.

That an excess of evaporation should not take place is the more peculiar from the fact that at its maximum it is the larger of the two and therefore has the greater quantity of matter to get rid of. Its summer, also, is shorter than the arctic one, so that it has the less time to dispose of its accumulations. The only other respect in which it seems to be differently circumstanced from its antipodes is in the character of its surroundings. About it are large blue-green areas which with intermissions stretch down in places to within less than ten degrees of the equator; whereas the other pole is continuously encircled for long distances by practically uninterrupted ochre. The character of the environment seems thus the only thing that can account for the difference in behavior and this proves the more plausible when we come to consider what those two classes of regions respectively represent.

In other ways as well the southern cap is the more self-contained. The rifts, indeed, break it up into separate portions and these in part remain as outlying detachments of the main body, as was notably the case in 1877 and in 1894, but they hardly have the permanency and importance of those similarly formed about the arctic pole. Nothing antarctic for instance compares with the subsidiary patch of the north polar regions lying in longitude 206°, which both

in Schiaparelli's time, and during the late oppositions as well was almost as fixed a feature of the arctic zone as the cap proper. Not quite so constant, however, and not so solid-looking a landmark is this patch for all its extent, which nearly equals the area of the more legitimate portion. It bears on its face a more pallid complexion as if it were thinner, and this is borne out by the fact that it occasionally disappears, an event which so far at least has never befallen the northern cap itself.

Less constant the southern one is to its own minimum than the northern. In some seasons, in most in fact, it reaches like the other a more or less definite limit of diminution which it does not pass. But this is not always the case. In 1894 it disappeared entirely at the height of its midsummer. The season was probably unusually hot then in the southern hemisphere of Mars.

In position the caps have something to say about physiographic conditions. Both caps at their minima are then irregular and the centre of the south one is markedly eccentric to the areographic pole. It lies some six degrees north along the thirtieth meridian. The northern one is also probably eccentric, but much less so, with a divergence not much exceeding a degree and of doubtful orientation. Not only are both caps not upon their respective poles but they are not opposite each other, the one lying in longitude 30°, the other

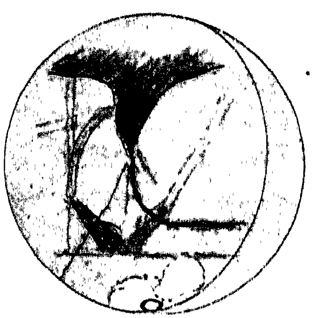
in 290°. This speaks, of course, for local action. In some wise this must depend on the configuration of the surface, yet so far as markings go there is nothing to show what the dependence is.

The eccentring of the caps is paralleled by the like state of things on earth. The pole of cold does not coincide in either hemisphere with the geographic pole. On the earth its position is largely determined by the distribution of the land-masses. Continents are not such equalizers of heat as oceans because of their conductivity on the one hand and their immobility on the other. In winter they part with their heat more quickly and convection currents cannot supply the loss. This accounting for thermal pole eccentricity is inapplicable to Mars because of the absence there of bodies of water. And it is significant that the degree the earthly poles of cold are out much exceeds what is the case on Mars. Possibly areas of vegetation there replace to some effect areas of water. It is certainly in favor of this view that the arctic regions there are more desert than the antarctic and that the north pole of cold occupies more squarely the geographic pole.

Not till 1903 did the actual starting again of either cap chance to be seen. Nor was this, indeed, a matter of hazard but of persistent inquiry by observation prolonged after the planet had got so far away that its scanning had hitherto been discontinued. Such search

beyond the customary limits of observation was essential to success, because of the relation of the axial tilt to the position of the planet in its orbit. At an opposition well placed for nearness, the tilt is such as largely to hide the pole and to present the polar regions too obliquely to view for effective scanning. This is true both of the arctic and the antarctic regions in turn. For the Martian axis being inclined somewhat as our own is to the plane of the planet's orbit, we at times see well and at times but poorly the arctic or antarctic zones.

The cap, the starting to form of which was thus caught, was the arctic one; the date 128 days after the northern summer solstice, or thereabouts, for as is perhaps natural the advent of the phenomenon partook of the wavelike advance of such things familiar on earth, an advance succeeded by a recession and then followed by another advance. So much is proof of local weather there as here. Hoar-frost was successively deposited and then melted off.



Deposition of frost.

What is significant, the deposition of the frost took place simultaneously over large areas. The very first patch of it,, in about longitude 320°, extended at one

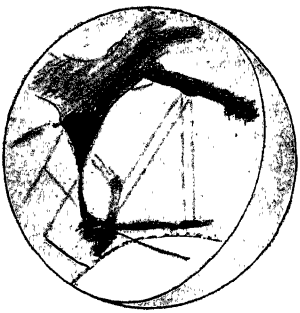
stroke down to latitude 55°. For it actually crossed the Pierius somewhat to the south. A second patch stretched to the east of the cap. Two wings these made to the kernel of cap itself. Through the wings could be marked the line of the canal: the Pierius upon the one side, the Enipeus upon the other. Such visibility of the canals through the white stretches proved the white not to be due to cloud suspended between us and them, but a surface deposit which found no lodgment upon the canals themselves. The same avoidance of dark markings was evidenced by the showing of the dark rim round the cap's kernel. Now, if the deposit were indeed hoarfrost, this failure to find permanent foothold on the dark markings is what we should expect to witness. For whether they were vegetation or water, equally in either case the frost would melt from them first. Probably they were both vegetal, though some doubt might exist about the latter, the band around the kernel. It was then August 20 in that hemisphere.

Such deposition over great stretches of country is perhaps not so surprising as it appears at first sight when seen from without in its totality. After all, something not unlike it occurs in our snow-storms when hundreds of square miles are whitened at once. Furthermore, with an atmosphere as thin as Mars seems to possess the temperature must be perilously near the

freezing-point in the arctic and subarctic regions at the close of summer.

Steadily, with intermissions, the white sheet increased until even the dark border to the cap became obliterate, the kernel showing at first through the veil like the ghost of what it had been, and then ceasing to be visible at all, its delimitations being buried under deeper and deeper depositions of frost.

The perennial portion of the cap was thus merged in the new-fallen snow. This marked the on-coming of the arctic winter in full force and happened even before the polar sun had wholly set. For the pole did not enter into the shadow till two of our months later, the autumnal equinox occurring 183 days after the summer solstice or 55 days after the first fall of frost. Then the pole passed into its star-strewn arctic night, a polar night of twice the duration of our own and the circumpolar regions entered upon their long hibernation of ten of our months.



First northern snow.

CHAPTER VII

WHITE SPOTS

IN addition to the polar caps proper and to the subsidiary polar patches that often in late summer flank them round about, other white spots may from time to time be seen upon the disk. In appearance these differ in no respect, so far as observed, from the arctic subsidiary snow-fields. Of the same pure argent, they sparkle on occasion in like manner with the sheen of ice. Equally with the polar caps they remain permanent in place during the period of their visibility and are themselves long-lived. Though by no means perpetual their duration is reckoned by weeks and even months, and they recur with more or less persistency at successive Martian years. That, when seen, they show in particular positions apparently unaffected by diurnal change precludes their being clouds, and this fact taken in connection with the character of their habitat is the puzzling point about them. For they affect chiefly the north tropic belt. They, or at least their nuclei, are small, about two or three degrees in diameter, and are not particularly easy of detection as a rule, though certain larger ones

are at times conspicuous. Chromatic, rather than formal, definition is necessary to their bringing out, as is witnessed by the superb colors the disk presents at the times when they are best seen. It is then that Mars puts on the look of a fire-opal.

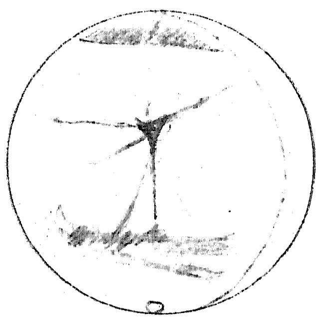
The first such spot to be noticed was one which Schiaparelli detected in 1879, at the second opposition in which he studied the planet. He called it the Nix Olympica, showing that he recognized in it a cousinship to the polar snows. Yet it lay in latitude 20° north, longitude [1] 131°, in the midst of the ochre stretches of that part of the disk. It was a small roundish white speck of not more than two thirds the diameter of the polar cap. Reseen by him in 1881, it failed to appear at subsequent oppositions and was not caught again until 1888. Then once more it vanished, not to be detected anew till many years after at Flagstaff, coming out rather surprisingly in 1903. It showed, however, in the same place as before; so that its position but not its existence is permanent.

A similar but smaller patch was apparent to Schiaparelli at the same opposition of 1879. This one which

[1] Martian longitudes are now reckoned from the Fastigium Aryn, the mythologic cupola of the world, a spot easy of recognition because making the tongue in the jaws of the Sabaeus Sinus. It further commends itself because of lying within a degree of the equator. The longitudes are reckoned thence westward all the way round, or to 360°.

he styled the Nix Atlantica lay between the Thoth and the Syrtis Major. It was about half the size of the Nix Olympica and has never since been seen, though it should have been had it continued to be what it then was.

On the other hand, phenomena of the sort undetected of Schiaparelli have been remarked at Flagstaff. On May 18, 1901, I was suddenly struck by the singular whiteness of the southeast corner of Elysium where that region bordered the Trivium. Elysium has a way of being bright but not with such startling intensity as this spot presented nor in so restricted an area as was here the case. The spot was so much whiter than anything I had ever previously seen outside the polar caps that it arrested my attention at once. And this the more that I had observed this same part of the planet the day before and perceived nothing out of the ordinary. Once detected, however, the spot continued visible. The next day it was there with equal conspicuousness, and now thrust an arm across the Cerberus, entirely obliterating the canal for the space of several degrees. In this salience it remained day after day till the



White in Elysium.

region passed from sight, to reappear with it six weeks later when the region again rounded into view. The hour of the Martian day seemed to make no difference in its visibility. It was seen from early morning till Martian afternoon, as late as the phase permitted. Clearly there was nothing diurnal about its revealing, and it lasted for at least three months and a half, until the planet got so far away that observations were discontinued.

It was to all appearances and intents snow. But now comes the singular fact about it. It lay within ten degrees of the equator and showed from the end of June to the latter part of August. To our ideas there could be no more inopportune place or time for such an exhibition. For it cannot have been due to a snow-capped peak, as we know for certain that there are no mountains in this, or in any other, part of the planet. Besides, it had not appeared in previous Martian years; which it infallibly would have done had it been a peak. Indeed, it baffles explanation beyond any Martian phenomenon known to me. It seems directly to contradict every other detail presented by the disk.

The phenomenon is thus unique in kind; it is not, however, unique as a specimen of its kind. The eastern coast of Aeria where that region borders the Syrtis Major is prone to a brilliance of the same sort. It is

a narrow belt of country that shows thus, nothing but the coastline itself, but this for a considerable distance stretching several hundred miles in length. It has stood out saliently bright now at every opposition which I have observed, beginning with 1894. Sometimes it has been described in the notes as bright simply, sometimes as white, and once, in 1901, as glistening at one point like ice. Yet when upon the terminator it has never stood forth as a mountain range should have done to declare its character.

It has been evident regardless apparently of the Martian season. In 1894 it was bright from October 25 to January 16 (Martian chronology); in 1896, from December 22 to January 7; in 1901, from July 13 to the 15th; in 1903, at about the same date and so in 1905. It was whitest during the latter oppositions, showing that the effect is most marked in its midsummer. All of the above instances of extra-polar white have been located within the tropics. Examples of the same thing, however, occur in the north temperate zone. Tempe, a region just to the west of the Mare Acidalium, is exceedingly given to showing a small white spot close upon the Mare's border in latitude 50° north. This spot, too, on occasion glitters as it were with ice. It is also at times very small. So that whereas much of Tempe is by nature bright but a small kernel of it is dazzling.

The list might be easily extended from the record book. Thus on March 1 and 2, 1903, the disk showed speckled with minute white spots, one in Arcadia in latitude 41° north, one in Tharsis near the equator, a third just north of the Phoenix Lucus in 10° south, and a fourth, the Nix Olympica, and on April 11, a glittering pin-point starred like a diamond the centre of the Pons Hectoris. On both these occasions the Martian season was summer; July 9 for the latter, June 21 for the former date.

White in the Pons Hectoris.

As one approaches the north pole spots of like character become more numerous. Especially are such visible north of the Mare Acidalium in the arctic region thereabout, from 63° to 75° north.

From so widespread a set of instances the only explanation which seems to fit the phenomena is that the mean temperature of Mars is low, not very much above freezing, and that whatever causes a local fall in the temperature results in hoar-frost. Such an explanation accords well with the distance of the planet from the sun and the thinness of its atmosphere. At the same time it shows that the mean temperature over the greater part of the planet the greater part of the time

is above the freezing-point and that consequently it is no bar to vegetation of a suitable sort.

That the hoar-frost should be found even at the equator may perhaps be due to the very thinness of the air-covering of Mars, which would tend to make the actual insolation more of a factor than it is with us, and by the great length of the Martian seasons. In midsummer the greatest insolation occurs in the arctic and temperate, not in the tropic regions; on the other hand, an atmosphere tends to accumulate heat for the tropics. With us the latter factor is prepotent; it would be less effective on Mars. Then again the double duration of summer would tend to emphasize insolation as the important factor in the matter. But it is possible that greater deposition plays a part in the matter. On earth the rainfall is greatest near the equator and something of the sort may be true of the zones of moisture on Mars. That the most striking spots are found to the west of large dark areas may in this connection have a meaning inasmuch as, such regions being vegetation-covered, the air over them is probably more moisture-laden.

One point about the position of the spots is of moment: they have all been found in the northern hemisphere or within ten degrees of it in the southern equatorial region. This seems at first a question of hemispheres; but when we consider that the light areas

of the surface are chiefly in the boreal hemisphere and in the south tropic belt, we perceive that it may be rather the character of the surface there than the particular hemisphere in the abstract that is decisive in the matter. Nevertheless, the austral hemisphere is the hemisphere of extremes, possessing a shorter, hotter summer and a longer, colder winter than its antipodes. This would not favor sporadic small depositions of frost in summer so much as would a climate of a more mean temperature.

From the relative lack of atmospheric covering over the planet we should expect the nights to prove decidedly cool, while the days were fairly warm. Of this we have perhaps evidence in a singular aspect shown by the Mare Acidalium in June, 1903. The account of it in the Annals reads thus: "On May 22 an interesting and curious phenomenon presented itself. On that day, so soon as the Mare Acidalium had well rounded the terminator on to the disk, at λ352°, the whole of its central part showed white, the edges of the marking alone remaining as a shell to this brilliant core. So striking was the effect that beside appearing in the drawing it found echo in the notes. The next day no mention is made of it, and a drawing made under λ20° shows the Mare as usual and the bright spot in Tempe in its customary place. Neither was anything of the sort noticed on the 24th and 25th.

But on the 26th, the day of the projection (upon the terminator), the effect of the 23d reappeared, the longitude of the centre being 332°. Fortunately on that day a further drawing was secured which enabled its subsequent behavior to be followed. Made three hours later than the other, the longitude of the centre being 13°, this drawing shows the Mare well on the disk, its whole area as dark as usual and with Tempe bright to the right of it toward the terminator. The terminator in question was the sunrise one, and we are offered two suppositions in explanation of the phenomenon: either the white was due to a morning deposition of hoar-frost which dissipated as the sun got up, or obliquity rendered some superficial deposit visible which more vertical vision hid. That the former inference is the more probable seems hinted at by the simultaneous appearance from the 19th to the 26th of other areas of white between the Mare and the pole. May 26 was 88 days after the northern summer solstice, and corresponded to July 31 on the earth." Annals, Volume III, § 564.

In this connection mention may pertinently be made of Schiaparelli's repeated observation of regions that whiten with obliquity, a proclivity to which he particularly noticed Hellas and certain 'islands' in the Mare Erythraeum to be prone. Here as with the Mare Acidalium we certainly seem to be envisaging cases of matutinal frost melted by midday under the sun's rays.

CHAPTER VIII

CLIMATE AND WEATHER

IN gazing at the successive phases presented by the polar caps as their annual history unrolls itself to view, beginning with vast white cloaks that in winter hide so effectively the planet's shoulders, to little round knobs that in summer sit like guardsmen's caps more or less askew upon the poles, the bodily eye sees only the glisten of far-off snow. The mind's eye, however, perceives something more: the conviction they carry of the presence of an atmosphere surrounding the planet. Elusive as water vapor is to sight for its transparency and to spectroscopic determination for its earthly omnipresence, recognition of its existence elsewhere by deduction raises such reasoning at once to a more conspicuous plane than it might otherwise assume. Especially is this true where the deduction is itself conclusive, as is here the case. For it depends on phenomena not its own, but which are in their turn dependent on it. We are not even beholden to any knowledge of the substance composing the caps for the fundamental inference that an atmosphere surrounds them. Whatever that substance were, the fact that

the caps dissipate and reform shows us with absolute certainty that they pass into the gaseous state, to be later solidified afresh. This gas constitutes of itself an atmosphere; while another phenomenon, to wit, their blue girdles as they melt, affirming their substance to be snow and ice, enables us to precise the fact that this gas is water vapor.

From such premise given us by the polar caps we are able to infer much more by the help of the kinetic theory of gases. But the speed of parting by a planet with its gases is conditioned by the mean speed of each gas. Water vapor will, therefore, go before nitrogen, oxygen or carbonic acid gas. If, then, we find it present over the surface of a planet we are assured of the possibility that the other three may be there too, and from the similarity of matter in space strong reason to suspect that they actually are.

Corroborative evidence of the accuracy of the deduction as to the presence of a Martian air is shown in several other ways; in the existence of clouds to begin with. Rare as they are, these certainly float at times over parts of the planet, although it is doubtful whether they can then be seen. Fortunately for assurance we have other ways of ascertaining their presence than that of obscuration. Nor is it of account to the argument that they should be few and far between, as they

unquestionably are. One single instance of such mediumistic support is enough to support the theory of a medium; and that instance has been more than once observed.

Direct evidence of atmosphere is further forthcoming in the limb-light. This phenomenon might be described as a brilliant obscuration. It is a circlet of illumination that swamps the features as they near the full edge of the disk, the limb of the planet as it is called. Obliteration of the sort is evident, more or less markedly, at all times, and is not due to foreshortening, as the broadest areas are affected. The fading out of the detail at the limb suggests nothing so much as a veil drawn between us and it, lighter in tint than what it covers. Such a veil can be none other than air or the haze and cloud that air supports. From its effect, impartial in place and partial in character, cloud is inadmissible as a cause and we are left with air charged with dust or vapor in explanation. Obscuration due to it should prove most dense at the limb, since there the eye has to penetrate a greater depth of it; just as on the earth our own air gives azure dimness to the distance in deepened tinting as the mountains lie remote.

Another bit of evidence lies in the apparent detection of a twilight arc. In 1894 measures made of the polar and equatorial diameters of the planet showed

certain systematic residuals left after all known corrections had been applied. The only thing which would account for them was the supposition that a twilight arc had been unconsciously seen and as unconsciously measured. In delicate quantities of the sort too great reliance cannot be put, but if the residuals be not referable to other cause they give us not only further evidence of an atmosphere, but at the same time our only hint of that atmosphere's extent. From them it would seem that the air must be rare, not more than about four inches of barometric pressure, as we reckon it, and probably less; a thin, high air more rarefied than prevails upon our highest mountain tops.

Corroborative of this is the aspect of the planet. From the general look of the disk a scant covering of air is inferable. For one of the striking things about the planet's features is their patent exposure to our sight. Except in the winter time of its hemisphere or in the spring after the greatest melting of the polar cap, nothing seems to stand in our way of an uninterrupted view of the surface, whether in the arctic, temperate, or tropic zones. From the openness of its expression, however, too much case should not be made as we really know but little of how an atmosphere-enshrouded planet would look. We find no difficulty in seeing objects a hundred miles away across the surface of the earth and yet the thickness of the air strata

in such horizontal traversing is many fold what it is when we look directly up. It is also out of all proportion laden with dust and smoke. In the purer regions of the earth, a clear air imposes but little bar to sight, and conjures up far things startlingly distinct.

Nevertheless, every evidence points to a thin air upon Mars: *a priori* reasoning, indirect deduction and direct sight. Now, from a thinness of atmosphere it would follow, other things equal, that the climate was cold. About this there has been much question, but less of answering reply. From the distance of the planet from the sun it is certain less heat is received by it than falls upon the earth in something like the ratio of one to two. But that the amount effective is as the amount received is far from sure. The available heat is much affected by the manner of its reception. A blanket of air acts like the glass of a conservatory, letting the light rays in, but hindering the heat rays out. The light rays falling on the ground or the air are transformed into heat rays that, finding the return journey less easy, are consequently trapped. All substances are thus calorifiers, but water vapor is many times more potent than ordinary air to heat-ensnaring. A humid air has a hothouse tang to it most perceptible. Now, what the relative percentage of water vapor in the Martian atmosphere may be we do not know.

The thinness of the Martian air has caused it to be likened to that upon our highest mountain peaks which are in large part covered with perpetual snow. But the comparison is not well founded. A peak differs materially from a plateau in the countenance it gives to the heat falling upon it. On a plateau each warmed acre of ground helps the retention of heat by its neighbor; while in addition to being destitute of side support the higher winds generated about an isolated peak blow its own caloric away. Still less does any analogy hold between the two when the plateau is a world-wide one.

From these considerations it is evident glosses are possible upon the bald idea of a much lower temperature prevailing on the Martian surface than on the earth's. Doubtless the theoretic cold has been greatly overdone. Reversely, recent observations tend to lower the apparent temperature disclosed by the features of the disk, and between the rising of the theoretic and the falling of the observed we are left with a very reasonable compromise and reconcilement as the result.

The various look and behavior of the surface of Mars point to a mean temperature colder than that of the earth, but above the freezing-point of water; for regions, at least, outside of the polar caps and during all but the winter months. Except at certain special spots, and possibly even there, frost is unknown at all times within the tropics and except in winter in tem-

perate latitudes. These anomalous localities, mentioned in the preceding chapter, may be said to be the exceptions that prove the rule of general non-glaciation. For if they be snow, they stand witness to its absence elsewhere upon the disk, and if they are not, they testify the more emphatically to the same effect.

As between different parts of the surface, the tilt of the Martian axis and the greater length of the Martian seasons, the one the same as, the other the double of, our own, tend to an accentuation of the heat in the temperate and arctic or antarctic zones. The greatest insolation on earth is not, as we might suppose, at the equator, but at the parallels of 43.°5 north and south; even the poles themselves receiving a quarter as much heat again on midsummer day as ever falls to the lot of the line. This broad physical fact is equally true of Mars, while in the matter of consecutive exposure Mars in summer outdoes the earth. For the longer the seasons, the more nearly does the effective heat approach the received amount. Thus both on the score of heat received and of heat husbanded these zones must be relatively warm. And this shows itself in the look of the surface. In summer it is clearly warmer within the polar regions than is the case on earth, to judge by the effect. In winter the cold is doubtless proportionately severe.

For the diurnal range of temperature we have less

data. There is evidence pointing to chilly nights, but it is meagre, and we are left to fall back on the cold of our deserts at night for analogic condition of the state of things over the Martian desert levels after the sun goes down.

If we are uncertain of the precise character of the Martian climate, we know on the other hand a good deal about the Martian weather. A pleasing absence of it over much of the planet distinguishes Martian conditions from our own. That we can scan the surface as we do without practical interruption day in and day out proves the weather over it to be permanently fair. In fact a clear sky, except in winter, and in many places even then, is not only the rule, but the rule almost without exceptions. In the early days of Martian study cases of obscuration were recorded from time to time by observers, in which portions of the disk were changed or hidden as if clouds were veiling them from view. More modern observations fail to support this deduction, partly by absence of instances, partly by other explanation of the facts. Certainly the recorded instances are very rare. Indeed, occasions of the sort must to any Martians be events; since only one possible example has presented itself to me during the course of my observations, extending more or less over eleven years. Even in this case there was no obliteration, though a certain whiteness overspread an area near

the equator temporarily. Position seemed to point to its identity with a cloud which made its appearance about that time upon the terminator, and lasted for some thirty-six hours. The cloud, however, showed evidence of being, not the kind with which we are familiar, but a dust-storm, in keeping, indeed, with the desert region (Chryse) in which it originated.

With the exception of sporadic disturbance of the sort the whole surface of the planet outside the immediate vicinity of the polar caps seems free from cloud or mist and to lie perpetually unveiled to space. In the neighborhood of the caps, however, and especially round about their edge, a very distinct pearly appearance is presented during the months at which the cap is at its maximum, or in other words, in the depth of its winter. Of a dull white hue and indefinite contour the phenomenon suggests cloud. Where it lies spread no markings are visible; an absence explicable by obscuration due an interposed medium, but equally well by seasonal non-existence of the markings themselves, which from the general behavior of these markings we know to be to some extent certainly the fact. Of the regions where the effect is noticeable, Hellas is the most striking. So conspicuously white during the winter of the southern hemisphere as to have been often mistaken for the polar cap, its ghost shows thus almost regularly every Martian year. What is as suggestive as it is striking,

the blanching is confined to the solid circle constituting Hellas and does not extend into the dark regions by which it is circumscribed. Hellas is as self-contained when thus powdered as when, in its normal ochre or abnormal red, it stretches like a broad buckler across the body of the disk. That the land there lies at a higher level than its surroundings is pretty certain, but that the difference can amount to enough to explain its silveriness as ice is improbable. In latitude Hellas is distinctly temperate, lying between the parallels of 55° and 30°; but on Mars this is no warrant of a like climate. Again, though close on the south to what constitutes the polar cap, it does not strictly form part of that cap, but occupies both in position and in kind a something intermediary between the frost-bound regions of periodic snow and the warmer ones of perpetual sunshine. It seems to be afflicted with the winter weather of the north of Europe, and to owe its pearly look at such times to the same cloud canopy that then distressingly covers those inclement lands.

Similar in behavior to it is the long chain of so-called islands that, beginning southwest of Thaumasia, runs thence westward even to the eastern edge of Hellas. These belt the planet in a west-northwesterly direction by a strip of territory from ten to fifteen degrees wide, the medial line of which begins at 55° south and ends in about 40°. They are parted from

the main bright areas by blue-green 'seas' of about the same width as themselves, the Mare Sirenum, the Mare Cimmerium and Mare Tyrrhenum. These 'seas' the white that covers the 'islands' never crosses; though the continent, as we may call it for convenience, descends at the east to 30° south. Since the 'seas' are not seas, the cause which might bound the snow, were they such, cannot be the cause here. Nevertheless, they have an effect of some sort on the isothermal lines as is shown not only by latitudinal comparison with the state of things in Hellas, but with that in Thaumasia as well. For 30° south is also the limit apparently of the white on Thaumasia, where ochre desert stretches ten degrees farther south still; the region in its southern part being white-mantled, in its northern part not. Here again, then, the ochre areas make exception to what affects the blue-green ones. Clearly the blue-green regions temper the action of what gives them wintry cloak. But why they should do this is not easy to explain on any supposition terrestrial or marine. Bodies of water tend to foster the formation of clouds; so, less markedly, do areas of vegetation. Neither the old ideas, then, nor the new lend themselves in explanation. It may be that while we here seem to be envisaging cloud we are in reality looking at hoarfrost. On the other hand, light cloud would show less, superposed over a dark background, than over an ochre

one; and this, the simplest of all explanations, may be the true one. It is facts like these that intrigue us in the study of the Martian surface by revealing conditions which render offhand analogy with the earth unsafe. Indeed, we are more sure of some things which appear too strange to be true than of others so simple on their face as to enlist belief. Among the most difficult and perplexing are meteorological problems like the above. Here we can only say provisionally that while cloud best answers to the appearance, frost best fits the cause. For vegetation might melt frost, yet not dissipate cloud. By raising our conception of the mean temperature the facts can, however, be reconciled and this is probably the solution of the difficulty after all.

As we saw in the annual history of the polar caps a dimness somewhat different affects the northern cap in May and June. After the melting of the cap is well under way a haziness sets in along its edge which befuddles its outline and effectually hides what is going on within it. When at last the screen clears away the cap is found to be reduced to its least dimensions. Such obstructing sheet looks to be more of the nature of mist caused by the excessive melting of the cap. Unfortunately, there are here no patches of blue-green to test a possible partiality in its behavior over such tracts; nor has similar action ever yet been remarked in the case of the cap of the southern hemisphere.

Regular recurrence at the appropriate season of the planet's year, together with extensive action at the time, takes this springtide mist to some extent out of the domain of weather into that of climate. For it prevails all round the cap and repeats itself in place as each fresh spring comes on. At least it has done so for the past three oppositions at which it has been possible to observe well the arctic zones. It is thus both general in its application and fixed in its behavior. Nevertheless, it betrays something of the fickleness which characterizes that more inconstant thing: weather. For it comes and goes, one thinks for good, only to find it there again some days later. Not less captious is the meteorologic action shown in the making of the new polar cap. When the northern one starts to form, vast areas of frost are deposited in a single night. These, however, are not permanent. The ground thus covered is during the next few days again partially laid bare. Then a new fall occurs, hiding the surface a little more completely than before, and the lost domain is more than regained. By such wave-like advance and recession the tide of frost creeps over and submerges the arctic regions as the late summer passes into the autumn. In this alternate coming and going with succeeding days, we have an unsteadfastness of action most fittingly paralleled by our own weather. It would seem that local causes there as here

are superposed upon the orderly progress of the seasons and though at the on-coming of the autumn the cold is steadily gathering strength, nevertheless warm days occur now and then to stay its hand, only to be succeeded in their turn by frosts more biting than before. Even on Mars nothing in the way of weather is absolutely predicable but impredicability.

CHAPTER IX

MOUNTAINS AND CLOUD

IN all ways but one our scrutiny of the planet is confined to such view as we might get of it from the car of a balloon poised above it in space; from which disadvantage-point we should see the surface only as a map spread out below us, a matter of but two dimensions. The exception consists in the observation of what are called projections; irregularities visible when the disk is gibbous upon that edge of the planet where the light fades off. Striking phenomena in themselves they are of particular value for what may be deduced from them. For by them we are afforded our only opportunity of gaining knowledge of the surface other than in plan and thus of determining between peak, plateau, or plain that to a bird's-eye view alike lie flattened out to one dead level.

It might at first be thought that our best chance of noting any elevations or depressions of the Martian surface lay in catching that surface in profile, by scanning the bright edge of it which stands sharp-cut against the sky and is called the limb. For this is practically what we do on earth when we mark a

mountain against the horizon and measure its height by triangulation. Unfortunately the method fails in the case of Mars because of the great distance we are away. Unless the planet were distinctly more generously equipped than the earth in the matter of mountains, nothing could be hoped from so forthright an envisaging. So relatively insignificant to the size of its globe is the relief of the earth's surface that an orange skin would seem grossly rough by comparison. The same proves true for Mars. With the greatest magnification we can produce, the Martian limb still appears perfectly smooth.

Luckily, while direct vision is thus impossible, oblique illumination enables us to get an insight into the character of the surface we had otherwise been denied. When mountains or valleys chance to lie upon the boundary of light and darkness, the rim of the disk known as the terminator in contradistinction to the limb where the surface itself comes to an end, they make their presence evident through an indirect species of magnification, the elongate effect of oblique lighting. With a practical instance of it every one is familiar who has walked by night along a road imperfectly starred at intervals by electric lights. Startled between posts by what seemed deep holes and high furrows he has involuntarily imitated a spavined horse for fear of stubbing his toes, only to encounter when

his foot fell a surface on contact surprisingly smooth. The slant illumination by lengthening the shadows had painfully deceived him into exaggerated inference of irregularity. What proves disturbing to a wayfarer misguided by arc lights is made to do the eye service when it comes to planetary interpretation. On the boundary of light and shade, those parts of the surface where it is sunrise or sunset upon the planet, the sun's rays fall so athwartwise as to throw enormous shadows from quite small elevations to an eye so placed as to view the surface with anything approaching perpendicularity. A mountain mass there will thus proclaim itself by protracted profile upon the plain in hundredfold magnification. Similarly a peak there will advertise its height by catching the coming or holding the lingering light at many times the distance of its own elevation away from the night side of the planet. Here, if anywhere, then, could mountains be expected to disclose themselves, and here, when existent, they have as a matter of fact been found.

Our own moon offers us the first and easiest example of such vicariously visible relief. When the moon is near the quarter, and for three or four days on either side of that, a keen eye can usually detect one or more knobs, like warts, projecting from its terminator, easily distinguished from the limb both by reason of

being less bright and of being bounded by a semi-ellipse instead of a semicircle. If a telescope or even an opera-glass be substituted for the eye, it is possible to see what causes them; the knob resolves itself into the illuminated rim of a crater separated from the main body of the visible moon by the seemingly black void of space. The peak has caught the sunlight, while its foot and the country between it and the illuminated surface still lies shrouded in shadow.

From measurement of the distance the sun-tipped peak seems to stand aloof from the line where the plain itself is touched by the light, the height of it above that plain may be calculated. In this way have been found the heights of the mountains of the moon. Incidentally, brain outstrips brawn. For pinnacles no Lunarian could scale, both for their precipitous inaccessibility and their loftiness, man has measured without so much as setting foot upon their globe. At each lunar sunrise and again at lunar sunset these old crater walls show their crescent coronets tipped the reverse way; and peaks higher than the Himalayas make gigantic gnomons of themselves with hands outstretched to grasp the plains.

In this manner a lunar peak of fifteen thousand feet shows its presence to the unaided eye. With so much for starting-point we can calculate how low an elevation could similarly be made out on Mars under a like

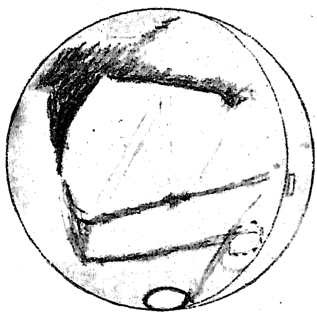
phase illumination. Now, in spheres of different diameters the distance out from the terminator for a given height is as the square root of the diameter. Mars has about twice the size of the Moon. In consequence, if we saw the planet at the same distance off as the Moon, the height of a peak upon it sufficient to cast an equal shadow or be seen at an equal separation from the terminator need be but two thirds as high. To see it thus equidistant a power of 250 or 300 is necessary, dependent on the opposition. Twice this power may at times be used, and by the same reasoning this would reduce the height sufficient to show by four or to something like 2500 feet. This, then, would be the theoretic limit of the visible, a limit needing to be somewhat increased because of the imperfection of our air.

Having found thus what should be visible on Mars we turn now to see what is. At once we find ourselves confronted with a very unlunar state of things. Common upon the face of the Moon, excrescences of the terminator are rare on Mars. The first ever seen was detected by a visitor at the Lick Observatory in 1888. Since then they have been repeatedly noticed both at the Lick and elsewhere. But although observers are now on the watch for them, they are not very frequently chronicled because not of everyday occurrence. Much depends upon the opposition; some approaches

of the planet proving more prolific of them than others. How rare they are, however, may be gathered from the fact that the last three oppositions have disclosed but one apiece.

An account of the great projection of May 25, 1903, will give an idea of the extent and interest of the phenomenon and will serve to show to what cause we must attribute all such that have been visible on Mars, for the behavior of this one was typical of the class.

About half past eight o'clock in the evening of May 26, 1903, Mr. V. M. Slipher, astronomer at Flagstaff, shortly after taking over the telescope then directed upon Mars, suddenly noticed a large projection about halfway up the terminator of the planet. He at once sent word of the fact and the observatory staff turned out to see it, for a projection has for workers on Mars the like interest that a new comet possesses for astronomers generally. In this case the phenomenon was specially potent in that it was the first to be detected that year. Its singularity was amply seconded by its size. For it was very large, its extent both in length and height being excessive. When I first saw it, the projection consisted of an



Projection on terminator.

oval patch of light, a little to the north of the centre of the phase ellipse lying parallel to the terminator but parted from it by darkness to the extent of half the projection's own width. It made thus not simply an excrescence but a detached islet of light. It was easily seen by all those present and was carefully studied from that time on by Mr. Slipher and me. Both of us made drawings of it alternately at intervals, as well as micrometer measures of its position.

Next to its great size, the most striking feature about it was its color. This, instead of being white or whitish, was ochre orange, a hue closely assimilated to the tint of the subjacent parts of the disk, which was the region known as Chryse. This distinctive complexion it kept throughout the period of its apparition. At the same time Baltia, a region to the north of it and synchronously visible close upon the terminator, showed whitish. The seeing was good enough to disclose the Phison and Euphrates double, the power a magnification of 310 and the aperture the full aperture of the 24-inch objective.

From the time it was first seen the detached patch of light crept in toward the disk, the illuminated body of the planet. Four minutes after I noted it the dark space separating it from the nearest point of the terminator had sensibly lessened. So it continued, with some fluctuations intrinsic to the atmospheric diffi-

culties of observations generally and to the smallness of the object itself, to become gradually less and less salient. It lasted for about forty minutes from the moment it had first appeared to Mr. Slipher and then passed from sight to leave the edge of the planet smooth and commonplace again.

The measures made on it showed that it lay when first seen in longitude 39°.7, latitude 18°.5 north, and that its highest point stood seventeen miles above the surface of the planet. It was three hundred miles long. These are my own figures, from which Mr. Slipher's do not substantially differ.

The return of the part of the planet where it had been seen was eagerly awaited the night after by both observers, to see if it would bring the projection with it. For only once a day is the same region of Mars similarly presented. But in order not to miss the projection, should it be ahead of time, observations were begun before it was due. Shortly after they were started, there appeared higher up the terminator and therefore farther north than had been the case the night before, a small projection. It was with difficulty made out and its position measured. Without careful watching it must have been missed altogether. As it was, it differed in every respect from that of the preceding day. It was not nearly so high, not nearly so large, and lay in a different place on the planet, being now

in longitude 31°.7, latitude 25°.5. Either the two, therefore, were totally different things or the projection had moved in the elapsed interval of time over seven degrees of latitude and eight degrees of longitude, a distance of three hundred and ninety miles in twenty-four hours. Where the previous projection had been nothing showed. On the following night, May 28, no trace of anything unusual could be seen anywhere.

We are now concerned to inquire to what this series of appearances could have been due. The first observers of projections on Mars had unhesitatingly attributed them to the same cause that produces projections on the Moon, to wit, mountains. Such they were held to be in France and at the Lick. This view, however, was in 1892 disputed by W. H. Pickering who considered them to be not mountains, but cloud. And this view was strongly supported by A. E. Douglass in a discussion of a large number of them observed in 1894 at Flagstaff. The mountain theory of their generation was finally shown to be untenable and their ascription to cloud conclusively proved to be the correct solution by the observations of a remarkable one made in December, 1900, and the careful study to which by the writer they were subjected. We shall now explain how this was done and we will begin by pointing out that the fact that only a single specimen of the phenomenon was visible at each of the

three oppositions of 1900, 1903, and 1905 was itself conclusive, rightly viewed, of their non-mountainous character. This conclusion follows at once from the isolateness of the phenomenon. For a mountain cannot change its place. Now, the shift in the aspect presented by the planet's disk from one night to the next is not sufficient to alter perceptibly the appearance shown by anything upon its edge on the two occasions. If, then, a peak stood out upon it one evening, the peak should again show salient when the region reached the same position upon the succeeding night. That nothing then was seen where something had previously been visible proved the phenomenon not that of a mountain peak, since what produced the projection was clearly not fixed in place and therefore not attached to the soil. Now the only other thing capable of catching the light before it reached the surface would be something suspended in the air, that is, a cloud. Deduction, therefore, from the rarity of the phenomenon alone showed that the projections must be clouds.

Their behavior in detail entirely corroborates this deduction from their intermittence. Such was shown by the action of the projection of December 6, 1900, as set forth in a paper before the American Philosophical Society and such again by that of the one of May 26, 1903, as we shall now note. To begin with, we notice that the projection seen on May 26 was not

found either *in situ* or in size on May 27 and had wholly vanished on May 28, though the seeing was substantially the same if not better on the two nights succeeding that of its original detection. Hence in its own instance this projection proved an alibi irreconcilable with the character of a mountain mass. But it did more. It not only was not on the second evening what and where it had been on the first, but the remains of it visible on the second occasion showed clearly that it had moved in the meantime. Furthermore it was disappearing as it went, for it was very much smaller after the lapse of twenty-four hours. The something that caused it was not only not attached to the soil, but was moving and dissipating as it moved. Only one class of bodies known to us can account for these metamorphoses and that is: cloud.

But what kind of cloud are we to conceive it to be? Our ordinary vapor clouds are whitish and this would be still more their color could they be looked at from above. The Martian cloud was not white but tawny, of the tint exhibited by a cloud of dust. Nor could this color have very well been lent it by its sunrise position, for other places equally situated to be tinged by the hues of that time of day, Baltia to wit, showed distinctly white. So that we must suppose it to be what it looked, a something of the soil, not beholden to atmospheric tinting for its hue; a vast dust-cloud

traveling slowly over the desert and settling slowly again to the ground.

Precisely the same general course of drifting disappearance was taken by the projection of December 7 and 8, 1900. And this, too, stood an unique apparition in the annals of its opposition. Clouds, then, and not mountains are the explanation of the projections on Mars, differing thus completely from the lunar ones.

CHAPTER X

THE BLUE-GREEN AREAS

DESCENDING now equatorwards from the polar regions, and their in part paleocrystic, in part periodic, coating of ice, we come out upon the general uncovered expanse of the planet which in winter comprises relatively less surface than on Earth, but in summer relatively more. Forty degrees and eighty-six degrees may be taken as the mean hiemal and æstival limits respectively of the snow on Mars; forty-five and seventy-five as those of the Earth. Whatever ground is thus bared of superficial covering on Mars lies fully exposed to view, thanks to the absence of obscuring cloud; and it is at once evident that the terrrane is diversified, patches of blue-green alternating with stretches of reddish ochre. Of the two opaline tints the reddish ochre predominates, fully five eighths of the disk being occupied by it.

It was early evident in the study of the surface of Mars that its ochreish disk was not spotless. Huyghens in 1659 saw the Syrtis Major. From this first fruit of areography dates, indeed, the initial recognition of the planet's rotation; for on noting that

the marking changed its place, he inferred a turning of the planet upon itself in about twenty-four hours. Thirteen years later he observed and drew it again and this time in company with the polar cap. Again, after eleven more years, he depicted it for the third time, and now so changed because of the different tilt of the planet toward the earth that it may be doubted whether Huyghens himself recognized it for the same. But that he drew it correctly a globe of Mars will at once show.

From such small beginning did areography progress to the perception of permanent patches of a sombre hue distributed more or less irregularly over the disk. Impressing the observers simply as dark at first, they later came to be recognized as possessing color, a blue-green, which contrasted beautifully with the reddish ochre of the rest of the surface. Cassini, Maraldi, Bianchini, Herschel, Schroeter, all saw markings which they reproduced. Finally, with Beer and Maedler, came the first attempt at a complete geography. In and out through the ochre was traced the blue; commonly in long Mediterraneans of shade, but here and there in isolated Caspians of color. With our modern telescopic means the dark patches are easily visible, the very smallest glass sufficing to disclose them. When thus shown they much resemble in contour the dark patches on the face of the Moon as seen with the naked eye. Now these patches were early taken for lunar

seas and received names in keeping with the conception; as the Sea of Serenity, the Sea of Vapors, and so forth. Following the recognition of a like appearance, like appellatives were given to the Martian markings; and the Mare Sirenum, or Sea of the Sirens, the Mare Cimmerium, and others sufficiently proclaim what was thought of them at the time they were thus baptized. Indeed, if a general similarity be any warrant for a generic name they were not at the time ill-termed. For, common to all three bodies, the Earth, the Moon, and the planet Mars, is the figuration of their surfaces into light areas and dark. In the Martian disk, as in the lunar one, we seem to be looking at a cartographic presentation of some strange geography suspended in the sky; the first generic difference between the two being that the chart is done in chiaroscuro for the Moon, in color for Mars. On mundane maps, we know the dusky washes for oceans; so on the Moon it was only natural to consider their counterparts as *maria;* and on Mars as 'seas.' Nor did the blue-green hue of the Martian ones detract from the resemblance.

But in something other than color these markings are alike. In fact, color could hardly be excuse for considering the lunar *maria* what their name implies, for distinctive tint is lacking in them, even to the naked eye. It was in form that the likeness lay. Their figures were such as our own oceans show; and allowing for

a sisterly contrast amid a sisterly resemblance, the lunar *maria* or the Martian seas might well have been of similar origin to those with which our schoolboy study of atlases had made us familiar. Thus did similarity in look suggest similarity in origin, and intuitive recognition clothe its objects with the same specific name.

Considerable assumption, however, underlay the pleasing simplicity of the correlation on other grounds, consequent not so much upon any lack of astronomic knowledge as, curiously, upon a dearth of knowledge of ourselves. We know how other bodies look to us, but we ignore how we look to them. It is not so easy to see ourselves as others see us; for a far view may differ from a near one, and a matter of inclination greatly alter the result. Owing both to distance and to tilt we lack that practical acquaintance with the aspect of our own oceans viewed from above, necessary to definite predication of their appearance across interplanetary space. Our usual idea is that seas show dark, but it is also quite evident that under some circumstances they appear the contrary. It all depends upon the position of the observer and upon the position of the Sun. Their usual ultramarine may become even as molten brass from indirect reflection; while on direct mirroring, they give back the Sun with such scarce perceptible purloining of splendor as to present a dazzling sheen

not to be gazed upon without regret. Canopied by a welkin they assume its leaden hue, while at the same time, their shores, less impressionable to borrowed lighting, show several tints darker than themselves. Surfaces so sensitive to illumination hardly admit of more accusable tint than a chameleon. Nevertheless, we are probably justified in our conviction that perpendicularly visaged, they would on the whole outdo in sombreness land round about them, and so be evident as dusky patches against a brighter ground.

One phenomenon we might with some confidence look to see exhibited by them were they oceans, and that is the reflected image of the Sun visible as a burnished glare at a calculable point. Specular reflection of the sort was early suggested in the case of Mars, and physical ephemerides for the planet registered for many years the precise spot where the starlike image should be sought. But it was never seen. Yet not till the marine character of the Martian seas had been otherwise disproved was the futile quest for it abandoned. Indeed, it was a tacit recognition that our knowledge had advanced when this column in the ephemeris was allowed to lapse.

On this general marine ascription doubt was first cast in the case of the Moon. So soon as the telescope came to be pointed at our satellite, it was evident that the darker washes were not water surfaces at all, but

very palpably plains. Long low ridges of elevation stood out upon them like prairie swells, which grew in visible relief according to the slanting character of the illumination. Cracks or rills, too, appeared near their edges and craters showed in their very midst. Patently solid they betrayed their constitution not only by diverse topography but by diversified tint. All manner of shades of neutral tone mottled their surface, from seeming porphyry to chalk. Belief perforce departed when the telescope thus pricked the bubble, evaporating as the water itself had done long before.

So much was known before the Mars' markings were named. Nevertheless, humanity, true to its instincts, promptly proceeded to commit again the same mistake, and, cheerfully undeterred by the exposure of its errors in the case of the Moon, repeated the christening in the case of Mars. So sure was it of its ground that what it saw was not ground, that though the particular appellatives of the several seas were constantly altered, rebaptisms, while changing the personal, kept the generic name. Dawes' Ocean, for example, later became l'Ocean Newton and later still the Mare Erythraeum, but remained set down as much a sea as before. About thirteen years ago, however, what had befallen the seas of the Moon, befell those of Mars: the loss of their character. It was first recognized through a similar exposure; but the fact was led up to and might

have been realized in consequence of quite a different line of evidence. The initial thing to cast doubt upon the seas being what they seemed to be was the detection of change in their aspect. That the detection was not made much earlier than actually happened shows how a phenomenon may elude observation if scrutiny be not persistent, and its results from time to time not carefully compared. Schiaparelli was the one who first noticed variation in the look of the seas, and the discovery was as much due to the assiduity with which he followed the planet opposition after opposition as to the keenness with which he scanned it. The noting of change in the blue-green areas constituted, in fact, one of the first fruits of systematic study of the planet. Change in configuration, that is, alteration of area, preceded in recognition alteration of tint. Thus the Syrtis Major showed larger to him in 1879 than it had in 1877. This was natural; difference of degree being a more delicate matter to perceive than its effect upon extent. From change of area his perception went on to change of tone. In his own words, what he noticed was this: *Memoria,* VI, 1888, "No less certain is it that, from one opposition to another, one notices in the seas, very remarkable alterations of tone. Thus the regions called Mare Cimmerium, Mare Sirenum, and Solis Lacus, which during the years 1877 to 1879 could be numbered among the most sombre on the planet,

during the succeeding oppositions became less and less black, and in 1888 were of a light gray hardly sufficient to render them visible in the oblique position in which all three found themselves. . . . On the other hand, at the very same moment, the Mare Acidalium and the Lacus Hyperboreus showed very dark; the latter indeed appeared nearly black, although seen as tilted as the Syrtis and the equatorial bays. The condition of the regions called seas is therefore not constant: so much is unquestionable. Perhaps the change produced in them has to do with the season of the planet's year."

Holding as he did the then prevailing view that the blue-green regions were bodies of water, he regarded those of intermediate tint as vast marshes or swamps, and he accounted for change of hue in them as due to inundations and occasions of drying up. In consequence of losing their water, the seas, he thought, had in places become so shallow that the bottom showed through.

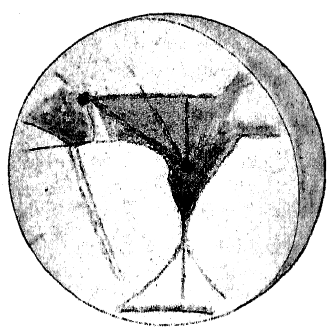
Plausible on the surface, this theory breaks down so soon as it is subjected to quantitative criticism. For the moment we try to track the water, we detect the inadequacy of the clew. The enormous areas over which the phenomenon occurs necessitates the establishing an alibi for all the lost water that has gone. Drying up on such a scale would mean the removal of many feet of liquid over hundreds of thousands of

miles in extent. To produce any such change in appearance as we witness, even on the supposition that these seas were none too deep to start with, would involve lowering the level of the water by from five to twenty feet throughout two thirds of the whole surface of the southern hemisphere. This would leave a heap of waters to be accounted for, bewildering in its immensity. The myriad tons of it must be disposed of; either by drainage into other regions or by being caught up into the sky.

In this emergency it might seem at first as if the polar cap of the opposite hemisphere offered itself as a possible reservoir for the momentarily superfluous fluid. But such hoped-for outlet to the problem is at once closed by the simple fact that when the lightening of the dark regions of the southern hemisphere takes place, the opposite polar cap has already attained its maximum; in fact, has already begun to melt. It, therefore, absolutely refuses to lend itself to any such service. This was not known to Schiaparelli's time, the observations which have established it, by recording more completely the history of the cap, having since been made. Indeed, it was not known even at the time when the writer, in 1894, showed the impossibility of the transfer on other grounds; to wit, on the fact of no commensurate concomitant darkening of the surface elsewhere and on the manifest non-complicity, if not impotency, of the Mar-

tian atmosphere in the process. The transference of the water to other dark patches in the northern hemisphere fails of sufficiency of explanation because of the limited extent of such areas on that side of the globe; while the air is quite as incapable of carrying away any such body of liquid, though the whole of it were at the saturation-point, not to mention that there exists no sign of the attempt. The reader will find this reasoning set forth in *Mars*, published eleven years ago. He will now note, from what has been said above about the northern polar cap, that continued observations since have resulted in opening up another line of proof which has only strengthened the conclusion there reached.

The *coup de grâce*, however, to the old belief was given when the surface of the dark areas was found to be traversed by permanent lines by Pickering and Douglass. Continued observation showed these lines to be unchangeable in place. Now permanent lines cannot exist on bodies of water, and in consequence the idea that what we looked on there were water surfaces had to be abandoned.



Lines in dark area.

Thus we now know that the markings on both the Moon and Mars which have been called *maria* are not in reality seas. Yet we shall do well still to keep the old-fashioned sonorous names, Mare Erythraeum, Mare Sirenum, and their fellows, because it is inconvenient to change; while, if we please, we may see in their consecrated Latin couching the fit embalming in a dead language of a conception that itself is dead.

CHAPTER XI

VEGETATION

SINCE closer acquaintance takes from the *maria* their character of seas, we are led to inquire again into their constitution. Now, when we set ourselves to consider to what such appearances could be due we note something besides sea, which forms a large part of our earth's surface, and would have very much what we suppose the latter's aspect from afar to be, not only in tone, but in tint. This something is vegetation. Seen from a height and mellowed by atmospheric distance, great forests lose their green to become themselves ultramarine.

To dispossess a previous conception is difficult, but so soon as we have put the idea of seas out of our heads a vegetal explanation proves to satisfy the phenomena, even at first glance, better than water surfaces. In their color, blue-green, the dark areas exactly typify the distant look of our own forests; whereas we are not at all sure that seas would. From color alone we are more justified in deeming them vegetal than marine. But the moment we go farther into the matter the more certain we become of being upon the right road.

With increased detection the markings they reveal and the metamorphoses they undergo, while pointing away from water, point as directly to vegetation. All the inexplicabilities which the supposition of water involves find instant solution on the theory of vegetal growth. The non-balancing of the areas of shading in their shift from one part of the disk to another, no longer becomes a circumstance impossible to explain, but a necessary consequence of their new-found character, denoting the time necessary for vegetation to sprout. The change of hue of vast areas from blue-green to ochre no longer presupposes the bodily transference of thousands of tons of substance, but the quiet turning of the leaf under autumnal frosts. Even the fact that they occupy those regions most fitted by figure to contain oceans fits in with the same conception. For that the Martian equivalents of forest and moorland, tree and grass, should grow now in the lowest parts of the planet's surface is what might not unreasonably be expected from the very fact of their being low, since what remained of the water would tend both on the surface and in the air to drain into them.

For the change in question to be vegetal it must occur at the proper season of the planet's year. This we must now consider. We have said that Schiaparelli detected change in the blue-green regions and suspected this change of seasonal affiliation. He inferred this

from piecing together the aspects of different seasons of different years as shown in consecutive Martian oppositions. To mark it actually take place in a single Martian year came later. In 1894, at Flagstaff, the southern hemisphere was presented during its late spring and early summer; it was observed, too, for many of our months in succession. During this time the planet was specially well circumstanced for study of the change in that hemisphere, both by reason of the appositeness of the season and of the unusual size of the disk. Advantage was taken of the double event to a recording of the consecutive appearances certain regions underwent, and the contrasted states thus exhibited were such as clearly to betoken the action of seasonal change. What Schiaparelli had thus ably inferred from diverse portions of different Martian years was in this case shown occurring in one and the same semestral cycle.

Usually the change of hue seems essentially one of tone; the blue-green fades out, getting less and less pronounced, until in extreme cases only ochre is left behind. It acts as if the darker color were superimposed upon the lighter and could be to a greater or less extent removed. This is what Schiaparelli noted and what was seen in 1894 at Flagstaff. Three views *en suite* of the chain of changes then observed are shown in *Mars*, the region known as Hesperia being central

in each. Comparison of the three discloses a remarkable metamorphosis in that "promontory," a rise into visibility by a paling of its complexion. Nor is the contrast confined to it; changes as salient will be noticed in the pictures over the other parts of the disk.

There have been instances, however, of a metamorphosis so much more strange as to deserve exposition in detail; one where not tone simply is involved, but where a quite new tint has surprisingly appeared.

On April 19, 1903, when, after being hidden for thirty days, owing to the different rotation periods of the two planets, the Mare Erythraeum, the largest blue-green region of the disk and lying in the southern hemisphere, rounded again into view, a startling transformation stood revealed in it. Instead of showing blue-green as usual, and as it had done six weeks before, it was now of a distinct chocolate-brown. It had been well seen at its previous presentation, so that no doubt existed of its then tint. At that time the Martian season corresponded to December 30 in our calendar. Eighteen Martian days had since elapsed, and it was now January 16 there. The metamorphosis had taken place, therefore, shortly after the winter solstice of that part of the planet. The color change that had supervened proved permanent. For the next night the region showed the same brown hue, and so it continued to appear throughout the days that it was visible.

Two months passed, and then the chocolate hue had vanished, — gone as it had come, — and the *mare* had resumed its usual tint, except for being somewhat pale at the south. It had come to be February 21 on Mars. Timed and tabulated, the metamorphosis through which the *mare* passed stands out thus: —

MARE ERYTHRAEUM 1903

MUNDANE DATE	DAYS BEFORE OR AFTER SUMMER SOLSTICE (BEFORE = − AFTER = +)	MARTIAN DATE	ASPECT
February 16	−10	December 16	Blue-green
March 20	+22	January 1	Blue-green
April 19	52	January 16	Chocolate
April 22	55	January 18	Chocolate
May 26	89	February 4	Faint chocolate
May 30	93	February 6	Faint chocolate
June 30	123	February 22	Faint blue-green
July 7	130	February 25	Faint blue-green

The culmination of the transformation seems to have taken place about 60 days after the southern winter solstice, or in the depth of the Martian winter of that hemisphere. This is certainly just the time at which vegetation should be at its deadest.

The northern and southern portions of the *mare* did not behave alike in taking on the chocolate tint. From the notes made about them during the opposition it appears that the latter was later than the former in

undergoing the metamorphosis, as will be seen from the following depth of the blue green estimated in percentages shown at different dates, calling the deepest tone ever exhibited by it unity.

Martian Date,	December (16)	January (1)	January (17)	February (5)	February (24)
	%	%	%	%	%
Northern	50	50	0	25	50
Southern	50	50	0	0	25

From this table we may place the lowest point of the blue-green tint as reached about the 22d of January for the northern, the 5th of February for the southern, part. This would indicate that the wave of returning growth came from the north, not the south; an important fact, as we shall see later in studying the action of the canals.

At the next opposition, in 1905, a recurrence of the transformation was watched for, and not in vain. It occurred, however, somewhat later in the Martian season. On December 27 of the planet's current year the Mare Erythraeum was still as usual, blue-green, nothing out of the ordinary being remarked in it; and so it was on its January 17, although the southern edge was darker than the northern. It looked certainly as if the metamorphosis were this year to be omitted. But such was not the case. When the region again came round, on February 1 of the Martian calendar, there the strange

tint was as unmistakable as it had been on its original occurrence. Not only was the Mare Erythraeum so colored, but on February 5 (Martian) the northern portion of the Mare Cimmerium was observed to be similarly affected. In the Mare Erythraeum the anomalous chocolate hue was confined to a belt between the latitudes of 10° and 20° south of the equator; in the Mare Cimmerium it stretched a little higher, from 10° at the west to 25° at the east. It is noteworthy that the southern portion of the latter showed blue at the time the northern showed brown. Then the metamorphosis proceeded as shown in the following table:—

MARE ERYTHRAEUM 1905

MUNDANE DATE	DAYS AFTER WINTER SOLSTICE OF SOUTHERN HEMISPHERE	MARTIAN DATE	ASPECT
January 25	12	December 27	Blue-green
March 6	52	January 16	Blue-green
April 4	81	January 31	Chocolate
April 12	89	February 4	Chocolate
April 30	107	February 13	Faint chocolate
May 8	115	February 17	Faint chocolate
May 12	119	February 19	Faint blue-green
June 11	149	March 6	Faint blue-green
June 15	153	March 8	Faint blue-green
July 16	184	March 23	Pale bluish green

Here, as in 1903, a chromatic rise and fall is evident; the culmination of the change occurring in Martian early February about ninety days after the winter solstice. That it was not of long duration is also indicated. If

we examine the evidence for the two portions of the *mare* separately, the northern and the southern, as in 1903, we find it as follows: —

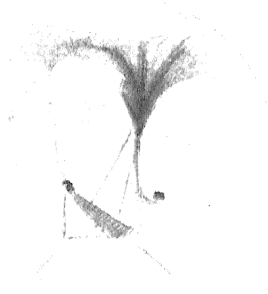
Martian Date,	December (27)	January (16)	February (2)	February (16)	March (7)	March (23)
	%	%	%	%	%	%
Northern	50	50	0	10	25	30
Southern	50	50	20	20	25	30

Here again a slight retardation in the advent of the metamorphosis is observable in the southern portion.

There would seem to be a difference in the time of the change between the two years of fifteen days, 1905 being by that much the later. But with points of reference themselves thirty days apart, it is possible the two more nearly coincided than here appears.

Unlike the ochre of the light regions generally, which suggest desert pure and simple, the chocolate-brown precisely mimicked the complexion of fallow ground. When we consider the vegetal-like blue-green that it replaced, and remember further the time of year at which it occurred upon both these Martian years, we can hardly resist the conclusion that it was something very like fallow field that was there uncovered to our view.

From the recurrence of the phenomenon on two successive years, it is likely that it annually takes place.



That it is seasonal can scarcely be doubted from the timeliness of its occurrence, and that different portions of its terrane successively underwent their metamorphosis shows further that it followed a law peculiar to the planet, to which we shall be introduced when we come to consider the phenomena of the canals.

Instances of relative hue in different dark patches corroboratory of seasonal variation, and therefore of vegetal constitution, might easily be adduced. Thus, in 1905 during the summer of the northern hemisphere, the Mare Acidalium was notably darker than the Mare Erythraeum to the north of it, which is what the law of seasonal variation would require, since it was June in the one, December in the other at the time. But we need not to add example to example or proof to proof, for there are no phenomena that contradict it. We conclude, therefore, that the blue-green areas of Mars are not seas, but areas of vegetation. Just as reasoning to a negative result drifts us to the first conclusion, so reasoning to a positive one lands us at the second.

CHAPTER XII

TERRAQUEOUSNESS AND TERRESTRIALITY

WITH the vanishing of its seas we get for the first time solid ground on which to build our Martian physiography. The change in *venue* from oceans to land has produced a complete alteration in our judgment of the present state of the planet. It destroys the analogy which was supposed to exist between Mars and our earth, and by abolishing the actuality of oceans there, seems, metaphorically, to put us at first all the more at sea in our attempt to understand the planet. But looked at more carefully, it turns out to explain much that was obscure, and in so doing gives us at once a wider view of the history of planetary evolution.

The trait concerned is cosmic. Study of the several planets of our solar system, notably the Earth, Moon, and Mars, reveals tolerably legibly an interesting phase of a planet's career, which apparently must happen to all such bodies, and evidently has happened or is happening to these three: the transition of its surface from a terraqueous to a purely terrestrial condition. The terraqueous state is well exhibited by our own earth at the moment, where lands and

oceans share the surface between them. The terrestrial is exemplified by both the Moon and Mars, on whose surfaces no bodies of water at present exist. That the one state passes by process of development into the other I shall now give my reasons for believing.

In the first place the appearance of the dark markings both on the Moon and Mars hints that though seas no longer, they were seas once upon a time. On the moon, not only does their shape suggest this previous condition, but the smooth and even look of their surfaces adds to the cogency of the inference. More important, however, than either of these characteristics, and confirmatory of both, is the fact that the great tracts in question seem to lie below the level of the corrugated surface, which is thickly strewn with volcanic cones. Their level and their levelness fay in explanation into one another. The first makes possible the former presence of water; the second speaks of its effect. For their flat character hints that these areas were held down at the time when the other parts of the surface were being violently thrown up. That they can themselves be cooled lava flows, their extent and position seem enough to negative; to say nothing of the fact that they should in that case lie above, not below, the general level. Something, therefore, covered them during the moon's eruptive youth and

disappeared later. Such superincumbence may well have been water, under which the now great plains lay then as ocean bottoms. Deep-sea soundings in our own oceans betray an ocean floor of the same extensive sort, diversified as on the moon. To call the lunar *maria* seas may not be so complete a misnomer after all; but only a resurrecting in epitaph what was the truth in its day.

Only doubtfully offered here for the Moon, for Mars the inference seems more sure. Here again the dark regions not only look as they should had they had an earlier history, but they, too, seem to lie below the level of the surface round about. When they pass over the terminator they invariably show as flattenings upon it, as if a slice of the surface had been pared off. Such profile in such pass is what ground at a lower level would present. Undoubtedly a part of the seeming depression is due to relative absence of irradiation consequent upon a more sombre tint, but loss of light hardly seems capable of the whole effect. In the case of Mars, then, as with the Moon, a mistaken inference builded better than it knew, if, indeed, we should rightly consider an inference to be mistaken which on half data lands us at the right door.

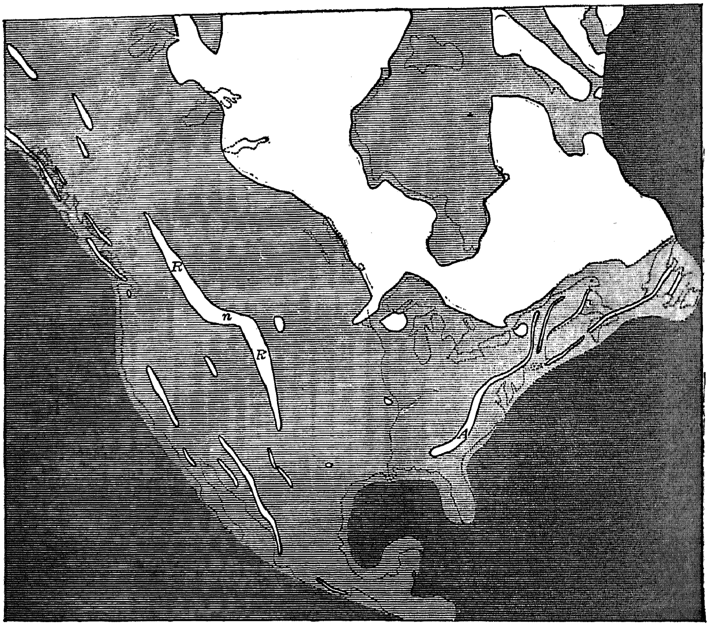
From the aspects of the dark regions we are led, then, to regard Mars as having passed through that stage of existence in which the earth finds itself at the mo-

ment, the stage at which oceans and seas form a feature of its landscape and an impediment to subjugation of its surface in its entirety. What once were ocean beds have become ocean bottoms devoid of that which originally filled them.

That the process of parting with a watery envelop is an inevitable concomitant of the evolution of a planet from chaos to world, we do not have to go so far afield as Mars and the Moon for testimony. Scrutiny reveals as much in the history of our own globe. Two sign-posts of the past, one geologic, the other paleontologic, point unmistakably in this direction. The geologic guides us the more directly to the goal.

Study of the earth's surface reveals the preponderating encroachment of the land upon the sea since both began to be, and demonstrates that, except for local losses, the oceans have been contracting in size from archaic times. So much is evidenced by the successive places upon which marine beds have been laid down. This suggests itself at once as a theoretic probability to one considering the matter from a cosmic standpoint, and it is therefore the more interesting and conclusive that, from an entirely different departure-point, it should have been one of the pet propositions of the late Professor Dana, who worked out conclusively the problem for North America, and published charts detailing the progressive making of that continent.

So telling is this reclaiming by nature of land from the sea that it will be well to follow Dana a little into detail, as the details show effectively the continuity of the process acting through æons of geologic time. At



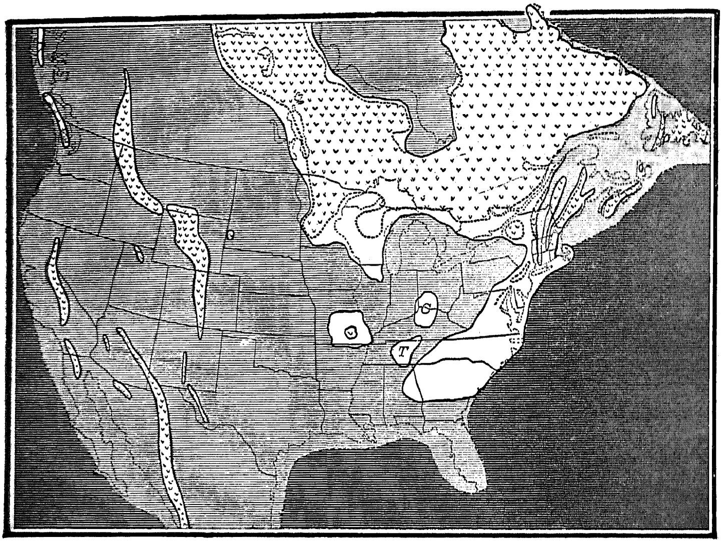
Map of North America at the close of Archæan time, showing approximately the areas of dry land. (From Dana's "Manual of Geology.")

the beginning of the Archæan age, or, in other words, at the epoch when stratified beds were first laid down, the earth reached a turning-point in its history. Erosion, superficial and sub-aërial, then set in to help restrict the domain of the sea. At this juncture North America consisted of a sickle of terrane inclosing Hud-

son's Bay and coming down at its apex to a point not much removed from where Ottawa now stands, in about latitude 45° — a Labradorian North America only. This, the kernel of the future continent, curiously symbolized the form that continent was later to take. For its eastern edge was roughly parallel to the present Atlantic coastline, although much within and to the north of it, while its western one was similarly aligned afar off to the now Pacific slope. Besides this continent proper, the Appalachian, Rocky Mountain, Sierra Nevada, and Sierra Madre chains stood out of the ocean in long, narrow ridges of detached land, outlining in skeleton the bones of the continent that was to be. The Black Hills of Dakota and other highlands made here and there islets in the sea.

Much the same backbone-showing of continents yet to be filled out was true of Europe, Asia, and South America. In Europe the northern countries constituted all that could be called continental land. Most of Norway, Sweden, Finland, Lapland, existed then, while the northern half of Scotland, the outer Hebrides, portions of Ireland, England, France, and Germany stood out as detached islands. From this, which is a fair sample of the proportion of land then to land now over the other continents so far as they are geologically known, we turn to consider more in detail the history of North America.

By the time the Upper Silurian period came in, the Appalachian highlands there had been greatly extended and joined to the Labradorian mainland by continuous

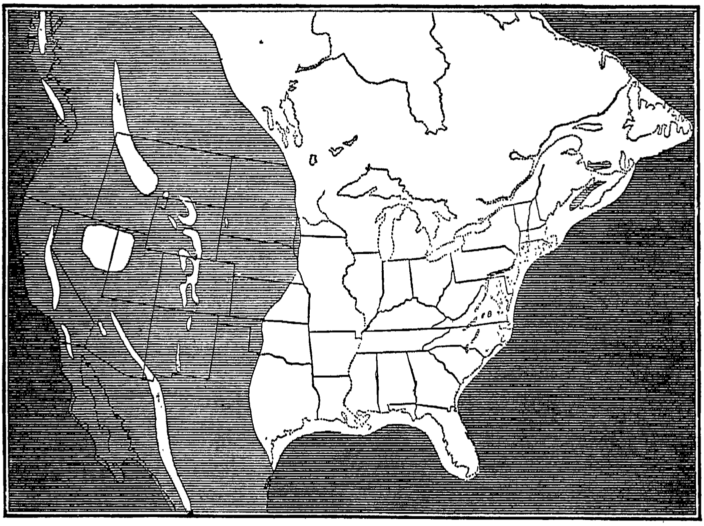


North America at the opening of the Upper Silurian. (From Dana's "Manual of Geology.")

territory; otherwise, no important addition had occurred, though islands emerged in Ohio, Kentucky, and Missouri.

At the commencement of the Carbonic era what are now the Middle states had begun to fill up from the north, and Newfoundland, from a small island in the Upper Silurian, had become a great promontory of Labrador, while the Eastern states region and Nova Scotia had risen into being. The movements closing

Paleozoic time upheaved from low islands the Appalachian chain. The earth's crust here crumpled by contraction upon itself; and the movement ended,

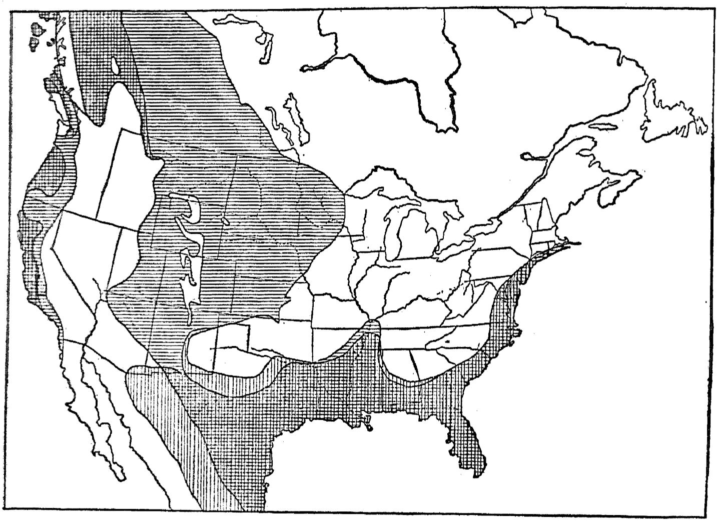


Map of North America after the Appalachian Revolution. (From Dana's "Manual of Geology.")

as Dana says, by making dry land of the whole eastern half of the continent, along substantially its present lines.

Mesozoic time was the period of the making of the West. It was an era of deposition and coincident subsidence, when the western land had its nose just above water at one moment to be submerged the next. Though on the whole this part of the continent was emerging, the fact was that, synchronously with the

sinking of the sea, much of the land from time to time sank too. The contraction which raised the Appalachian Mountains at the beginning of the period and that

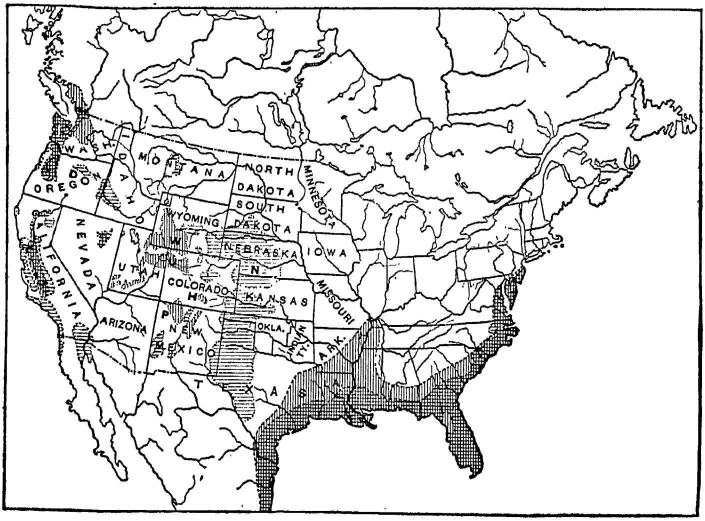


North America in the Cretaceous period. (From Dana's "Manual of Geology.")

of the Rockies at its close overdid the necessities of the case and caused subsidence elsewhere. The south-eastern portion of the continent suffered most, the West on the whole materially gaining. In the Triassic and Jurassic eras the gain was pronounced; it occurred in the Cretaceous also, but with much alternation of loss. Finally, at the close of the Cretaceous, the continent, except for a prolonged Gulf of Mexico and vast internal lakes, was substantially complete.

The filling up of these lakes and the reclaiming of

land from the Gulf of Mexico constituted the land-making work of Tertiary times. The extent of the lakes in the Eocene era is held to show that the general



Map of North America, showing the parts under water in the Tertiary Era; the vertically lined is the Eocene. (From Dana's "Manual of Geology.")

level of the mountain plateau was low and rose later. So that the gain by the land at this time was greater than the map allows to appear. By the beginning of the Quaternary epoch the continents had assumed their present general area, and since then their internal features have alone suffered change.

A similar rising from the sea fell to the lot of Europe, though it has not been detailed with so much care. The skeleton of that continent was at the beginning of depositary time much what it is to-day, but a great in-

land sea occupied the centre of it, which, as time went on, was gradually silted in and evaporated away, notably during the Upper Silurian period.

From all this it is pretty clear that, side by side with alternating risings and sinkings of the land, there was a tolerably steady gain in the contest by which dry ground dispossessed the sea. We may, of course, credit this to a general deepening of the ocean bottoms due to crumpling of the crust, but we may also impute it to a loss of water, and that the latter is, at least for a part, in the explanation the condition of the Moon and Mars makes probable.

Paleontology has the same story of reclamation to tell as geology, and with as much certainty, though its evidence is circumstantial instead of direct and speaks for the growing importance of the land in the globe's economy since the beginning of depositary time, and thus inferentially to its increasing extent. Fossil remains of the plants and creatures that have one after the other inhabited the earth show that the land has been steadily rising both in floral and faunal estimation as a habitat from the earliest ages to the present day. The record lies imprinted in the strata consecutively laid down, and except for gaps reads as directly on in bettering domicile as in evolutionary development.

In Archæan times we find no undisputed evidence of life either vegetal or animal. But beds of graphite

and of limestone point to the possible existence of both. Even anthracite has been found in Archæan rocks in Norway and also in Rhode Island. Whether Dawson's Eozoon Canadense be a rhizopod or a crystal, doctors of science disagree. Dana, while admitting nothing specific, deems it antecedently probable that algæ and later microscopic fungi related to bacteria existed then, living in water well up toward the boiling-point. Indeed, it is practically certain that invertebrate life existed, because of its already well-developed character in the next era. The like antedating is inferable for the whole record of the rocks. Relatively their history is undoubtedly fairly accurate, but absolutely it must be shifted bodily backward into the next preceding era to correspond with fact not yet unearthed.

In the Lower Cambrian, when first the existence of life becomes a certainty, that life, so far as known, was wholly invertebrate and wholly marine; rhizopods (probably), sponges and corals, echinoderms, worms, brachiopods, mollusks, and crustaceans grew amid primitive seaweed and have left their houses in the shape of shells while perishing themselves. Their tracks too have thus survived. The trilobites, crustaceans somewhat resembling our horseshoe crab, were the lords of the Cambrian seas and marked the point to which organic evolution had then attained. Their aquatic character as well as their simple type is shown

by their thoracic legs having each a natatory appendage.

In the next era, the Lower Silurian, the fauna and flora were still marine, although of a higher order than before, and in the Trenton period, the upper part of the era, the earliest vertebrates, fishes, come upon the scene: ganoids and possibly sharks. Nothing terrestrial of this period has yet with certainty been unearthed in America. Europe would seem to have either been more advanced then or better studied since, for there the first plant higher than a seaweed has been dug up, one of a fresh-water genus betokening the land; while in keeping with this the first insect, an hemipter, also has been disinterred. Both the geography and the life of the Eopaleozoic period Dana styles "thalassic."

Neopaleozoic time, beginning with the Upper Silurian, marked the emergence of the continents, and following them the emergence of life from the water on to this land. In the lower beds of the Upper Silurian in America we find only the aquatic forms of previous strata, but in a higher one we come in marshes upon plants related to the equiseta or horsetails. In England land plants appear for the first time in these latest Silurian beds and in the schists of Angers have been preserved ferns. In both the old world and the new fossil fishes are found and the oldest terrestrial species of scorpions. But the great bulk of forms was

still marine; corals, crinoids, brachiopods, trilobites constituting the principal inhabitants. At this time the seas were warm, having much the same temperature between 65° and 80° north as between 30° and 45°; the prevalence of a general temperate tropicality being shown by the fact that the common tropical chain corals lived in latitude 82° north.

In the Devonian era, the Old Red Sandstone, fishes grew and multiplied, increasing in size apparently through the era, and in the last period of it reaching their culminating point. These pelagic vertebrates much surpassed in structure the terrestrial population of the time, which was of a low type and consisted of invertebrates such as myriapods, spiders, scorpions, and insects; for the land was only making. In the mid-Devonian, forests of a primitive kind covered such country as there was, an amphibious land, composed of jungles and widespread marshes. Tree ferns made the bulk of the vegetation, but among them grew also cycads and yews. Mammoth may-flies flitted through the gloom of these old forests, but no vertebrate as yet had left the sea.

Following upon the Old Red Sandstone were laid down the Carbonic strata, and with the Carbonic entered upon the scene the advance scouts of an army of progress evolutionarily impelled to spy out the land — the first amphibians. They made their début in the

Subcarboniferous section of the era, the oldest of the three periods into which the Carbonic is divided, crawling out of the sea to return again and leaving but footprints at first on the sands of time. In the second period, the Coal-measures proper, they ventured so far as to leave their skeletons on terra firma, or rather infirma, while their tracks there show them to have been now in great numbers. In this manner the ancestors of the oldest land inhabitants began to struggle out of the sea. In the Permian, the third and latest period of paleozoic times, we find their descendants established in their new habitat, for in it we come upon the first reptiles. Such possession marks a distinct step up in function as in fact, for while amphibians visited dry land, reptiles made it their home. The getting out of the water had now, in the case of the more evolved forms, become an accomplished fact. The reptiles were, indeed, the lowest and most generalized of their class, Rhynchocephalians, "beak-headed" species that by their teeth proclaim their marine origin and their relationship to the great amphibians that still felt undecided where to stay. Meanwhile, in Europe dragon-flies, two feet across, possessed the air; while amphibians there, as here, ancestrally preceded reptiles in occupying the land.

Mesozoic times were, *par excellence*, the age of monsters; for the Triassic (the New Red Sandstone),